UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 194

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REVISION OF BUREAU OF RECLAMATION PUBLICATION "MEASUREMENT OF IRRIGATION WATER" PROGRESS REPORT

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By

H. M. Martin

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Denver, Colorado

February 15, 1946

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
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Laboratory Report No. 194
Hydraulic Laboratory
Compiled by: H. M. Martin
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and criticism

Subject: Revision of Bureau of Reclamation publication "Measurement of Irrigation Water" - Progress Report.

INTRODUCTION

In accordance with the provisions of a letter dated July 31, 1945, from the Commissioner to the Branch of Design and Construction, work was begun in November, 1945 on the compilation of a manual to supersede the Bureau booklet "Measurement of Irrigation Water". Progress on the preparation of the manual and the developments arising therefrom are the subjects of this report. The accompanying manuscript is a compilation of material for the tentative edition of the publication. It has not been given final editing for printed reproduction.

The chief purpose of the manual is to make available in a single reference, tables, charts, formulas, and descriptive matter useful for the measurement of irrigation practice. The tables, charts, and formulas are incorporated in the descriptive matter for clarity and continuity. It is intended primarily for the use of irrigation works operators, ditch riders and attendants. However, it is believed that the information incorporated in the manuscript will be useful to engineers engaged in the design of irrigation water measurement devices and structures, as well as those engaged in irrigation administration.

Methods not treated in previous editions are included for the reason that many such methods may well be used on projects that have advanced to a high degree of development, and for the sake of completeness. Many of the lesser known methods may be used only as approximate means of determining discharge of open channels or pressure conduits. Some of them can be utilized only by experienced engineers familiar with the particular specialty on which such methods are based. However, the brief presentation of each of such methods may serve both operating personnel and designers as a reminder of the availability of these special methods.

SUGGESTIONS AND RECOMMENDATIONS FOR REVISIONS

At the outset, letters dated December 3, 1945, were written to the state engineers, or equivalents, of seventeen western states advising that the Bureau is revising its publication on the measurement of irrigation water, requesting copies of, or citations to, the manuals used by their offices and inviting comment and suggestions on the composition and treatment of the subject matter. Several offices made particularly constructive and helpful replies.

Letters from the state engineers revealed the fact that there is no universally used handbook, manual or reference on the subject of irrigation water measurement in general. A summation of the information and suggestions of the replies follows:

State	Brief of Reply
Arizona	No manual or regulations relative to water measurement. Three principal methods: Current water, Parshall flume, weirs and Clausen-Pierce gage.
California	References generally used: University of California Agricultural Experiment Station Bulletin 588, "Measuring Water for Irrigation"; "Stream Flow" by Grover and Harrington; Colorado Experiment Station Bulletin 423, "The Parshall Measuring Flume"; Colorado Experiment Station Bulletin 488, "Improving the Distribution of Water to Farmers by use of the Parshall Measuring Flume"; Farmer's Bulletin No. 1683, U. S. Department of Agriculture "Measuring Water in Irrigation Channels." Principal methods: Parshall flume, current meter, Collins flow tubes and weirs.

Colorado	No reply.
Idaho	Reference generally used: University of Idaho Agricultural Engineering Section, Extension Circular No. 43, "Farm Water Measurement."
Montana	Reference generally used: University of Montana Agricultural Experiment Station, "Measurement of Irrigation Water, a handbook of discharge tables"; a mimeographed booklet published by State Water Conservation Board of Montana, entitled "Free Flow Discharge for Parshall Flume"; "Calco Metergate" tables; Principal methods: Weirs, Parshall Flume, Calco Metergate, and submerged orifices.
Kansas	No reply.
Nebraska	References: Geological Survey Water-Supply Paper 888, "Stream-gaging Procedure"; Bulletin No. 387, Colorado Experiment Station; Farmers' Bulletin No. 1683, U. S. Department of Agriculture; Bulletin 488, Colorado Experiment Station; Principal methods: current meter, Parshall flume, weirs, submerged orifices.
Nevada	Handbook "Common Methods of Measuring Water as Practiced in Western States," State Engineers Office, Carson City, Nevada.
New Mexico	References: Geological Survey Water-Supply Paper 888, "Stream-gaging Procedures"; Principal method: Parshall Flume.
North Dakota	No comments in reply.
Oklahoma	No comments in reply. Have no practice at present time.
Oregon	No manual adopted. Principal methods: Weirs, Parshall flume, and Calco metergate. Reference on current meter measurements: U.S.G.S. Water Supply Papers.

South Dakota	References: Handbook of Water Control, Hardesty Mfg. Co., "Common Method of Measuring Water as Practiced in Western States," State Engineers Office, Carson City, Nevada; "Irrigation Pumping Plants," M. H. Davison, Kansas State Board of Agriculture.
Texas	No comments or recommendations.
Utah	No reply.
Washington	References: "The Measurement of Water by Cipolletti Weirs with Table of Discharges," State Supervisor of Hydraulics, Olympia, Washington. No comments or recommendations.
Wyoming	References: "Common Methods of Measuring Water as Practiced in Western States," State Engineers Office, Carson City, Nevada; "Measurement of Irrigation Water," Bureau of Reclamation. Recommended: Parshall flume be treated extensively with the inclusion of tables. Illustrations of weirs, and submerged orifices were suggested.

Letters dated December 17, 1945, were also addressed to Regional Directors requesting their comments and suggestions, as well as those of their representative projects, as to the composition of the handbook, including the treatment of subject matter and format. Among the additions and modifications recommended for the revision received to date are:

a. A broader and more comprehensive treatise on the Parshall flume, including discharge tables for several sizes; method of determining required size for individual installations; conditions to be watched with caution, effects in ditch above the structure for instance; picture illustrations of good and bad installations with adequate explanatory notes; type of recorded gages to be used with flumes of large size; cost data for various sizes and types as of certain years; rating tables for Parshall flumes operating under high percentages of submergence.

b. A treatment of the use and care of current meters including the method of observations to obtain velocity, manner of dividing cross section into segments, computing discharge from velocity and area, and the description and manner of use of the type A meter, BTA meter, modified 616 meter. A breakdown photograph or drawing of the various parts together with their names was recommended to facilitate care and procurement of current parts. A sample form of complete current meter measurements and complete field notes was recommended as an aid to training hydrographers.

c. Improvement of format. In this connection it was suggested by one Regional Director that the 4-5/8-inch by 6-5/8-inch size is quite popular with project managers and water masters. It is small and compact and can be carried with ease on the person or in the glove compartment of a car. A project superintendent recommended that the revision be enlarged in size to about the same as the "Concrete Manual" or "Hydraulic and Excavation Tables" with a similar cover. It was recommended that generous use be made of pictures, sample diagrams, curves and computations.

d. A paragraph on measuring gates, such as the Calco measuring gate.

e. A treatise on 90-degree V-notch weir for the measurement of small quantities of water.

f. A discussion of the installation, operation, and care of gaging station, and equipment.

g. A discussion of the Bureau's design of "flume and rating section," otherwise known as the measuring control.

h. A description of the constant head orifice turnout together with tables for its operation.

i. Discharge tables for Cipolletti weirs to include widths up to 12 feet and greater.

j. Data, in addition to that currently published, be presented on the determination of the coefficient of discharge over ogee crests, together with tabular or graphical means of determining the effect of depth of water ahead of the crest on the coefficient of discharge.

k. An index to the contents of the handbook.

l. Introductory chapter discussing aspects of measurement of irrigation water throughout the Bureau bringing out problems in various sections of the country requiring different methods, equipment necessary.

m. General discussion of other methods, such as the Clausen-Pierce gage, rating turnouts by experimentally determining discharge "C," approximate methods such as the use of floats, salt velocity and color velocity method.

A review of the available literature on the subject disclosed that much of it has been published by the various Agricultural Experiment Stations of western state universities. To get a well-rounded opinion from writers on the subject an outline of the tentative edition of the manual together with a copy of the old fifth edition of the booklet, was mailed to the directors of the following experiment stations, inviting comments and recommendations:

Utah Agricultural Experiment Station	Logan, Utah.
Montana Agricultural Experiment Station	Bozeman, Montana.
Oregon Agricultural Experiment Station	Corvallis, Oregon.
Idaho Agricultural Experiment Station	Moscow, Idaho.
California Agricultural Experiment Station	Berkeley, California.
Colorado Experiment Station	Fort Collins, Colorado.

The outline enclosed was substantially the same as the table of contents of the manuscript which follows in this report. The purpose of the publication was explained to make an objective review possible.

To date, five replies have been received. Four replies indicate that the outline proposed for the tentative edition is considered to be satisfactory and adequate. One of these correspondents criticized the composition of table 1, and suggested that fewer decimal significant figures would be much easier to handle and for most practical purposes would be adequate in accuracy. Due to pressing current work the fifth correspondent was unable to offer an analysis immediately.

In consultation with members of the design departments responsible for the design of water-measuring devices for projects now under design or construction, it was found that the constant-head orifice-turnout should be calibrated to assure accurate measurements under various conditions likely to be encountered in actual practice. A program of tests on a one to two scale model of this device is now being conducted and the calibration data developed therefrom will be incorporated in the printed tentative edition.

In addition, a thorough search was made of the available literature on the subject, a bibliography compiled, and the constructive portions were used in the compilation of the manuscript.

DEVELOPMENT AND RESEARCH

There is a demand from the field for improvement in water measurement practice. A great many metering devices have been developed for the measurement of the flow of water. Several meters with moving parts have been used with varying success. The ideal meter would employ no or few moving parts, would create a small head loss and would require little maintenance. Probably the most widely used and useful development in the irrigation water measurement field in the past generation is the Parshall flume.

The design departments of the Bureau have developed several devices and structures for water measurement, some now in completed form and some in preparation. A well planned and coordinated program of development and testing in cooperation with projects in which the new developments will be used, and the design departments would doubtlessly produce refinements and economies in the practice.

STYLE AND FORMAT OF HANDBOOK

In view of the recommendations so far received from the field offices of the Bureau and the favorable comments by the Experiment Station on the outline of the revised edition based on these recommendations, the attached manuscript is proposed as the first draft, subject to completion by insertion of calibration data on the constant-head orifice-turnout, to additions or modifications found desirable from suggestions yet to be received from field offices, and subject to editing for reproduction in quantity.

It is proposed that the manual be prepared in a tentative edition in the form and style used for the "Concrete Manual," fourth edition, October 1942, for temporary use within the Bureau for soliciting field comments and criticism which would aid in preparation of a regular edition.

In the attached manuscript many tables and figures occupying full pages will be reduced to quarter or half-page size in the printed edition and distributed in the text for continuity, clarity, and interest. Additional photographs of typical standard water measurement devices and structures in operation may be desirable, and may be taken during the coming irrigation season.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Measurement of Irrigation Water

- - -

A Manual for the
Measurement of Irrigation Water

Tentative Edition

DENVER, COLORADO
1946

9

NOTICE

This Manual is issued strictly for temporary use within the Bureau and for soliciting field comments. A regular edition in final form will be issued later.

Suggestions, corrections, and criticism are invited from the field offices and should be forwarded to the Branch of Design and Construction not later than January 1, 1947.

Copies of the Manual in its present form are not available for sale to the public.

Preface

This Manual supersedes the booklet "Measurement of Irrigation Water" first published in 1913, by the United States Reclamation Service and the fifth and most recent edition of which was published by the Bureau of Reclamation in February 1940.

This Manual has been compiled in tentative edition for limited distribution to Bureau projects and to state engineers of western states and agricultural experiment stations many of whom contributed comments and suggestions on the subject matter.

The chief purpose of this publication is to make available in a single reference, tables, charts, formulas, and descriptive matter useful for the measurement of irrigation water for almost any condition which might be encountered in the irrigated western United States. It is intended primarily for the use of irrigation works operators, ditch riders, and attendants. It is hoped, however, that the information contained herein will be useful for engineers engaged in the design, operation, and maintenance of irrigation water measurement devices and structures.

In this edition methods not treated in the booklet have been included for the reason that many such methods may well be used on projects that have advanced to a high degree of development, and for the sake of completeness.

Many of the lesser known methods may be used only as approximate means of determining the discharge of open channels or pressure conduits. Some of them can be utilized only by experienced engineers familiar with the particular specialty on which such methods are based. It is believed, however, that each of the methods discussed may prove useful in the measurement of irrigation water for the special conditions to which they are adaptable.

A rather representative survey of Reclamation projects and western state engineer departments discloses that for large canals and rivers the publication Geological Survey Water-Supply Paper 888 - dated 1943, "Stream-Gaging Procedure" a manual describing methods and practices of the Geological Survey, U. S. Department of the Interior, is widely adopted and is generally regarded as the accepted authority on the subject. The treatment of stream-gaging herein is much briefer but is believed to be sufficient for most irrigation water measurement operations. Some recent developments of current meters and equipment are described.

The more lengthy and often-used tables of equivalents and discharges of the various measurement devices are collected in Section 84, Part IV to facilitate their use.

A work of this kind is, to a great degree, a recompilation of the work of others, and a great many books and publications have been necessarily consulted. Reference to such use is made in the bibliography following the text material.

The Bureau gratefully acknowledges the interest of all those who offered suggestions for the improvement of the manual.

The Bureau is especially indebted to the Chief of the Division of Irrigation, Soil Conservation Service, U. S. Department of Agriculture for permission to use material on the Parshall flume, much of which was extracted directly from the bulletins on the subject prepared by the Soil Conservation Service in cooperation with the Colorado Agricultural Experiment Station; also to the directors of the Agricultural Experiment Stations of Colorado, Utah, Idaho, California, Oregon, and Montana, for suggestions and material offered; and to the state engineers, or their equivalents, of seventeen western states for comments and suggestions offered.

CONTENTS

13

CONTENTS (Cont'd)

14

CONTENTS (Cont'd)

CONTENTS (Cont'd)

Section | Page

Part III - Pressure Conduits

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

18

LIST OF TABLES

LIST OF TABLES (Cont'd)

PART I

CHAPTER I - INTRODUCTION

1. Introduction. The economical use of irrigation water depends, to a great extent, on its accurate measurement. In view of the rapidly increasing utilization of all available irrigation water resources and the possible increase in the value of such resources, the best practice of measurement of irrigation water is fundamental to good irrigation management.

The chief purpose of this manual is to describe the more common and standard methods and devices used by the Bureau of Reclamation in the measurement of irrigation water in the western United States and to acquaint the irrigation system operators with several methods many of which, although at the present state of the practice cannot be classed as standard, may be used with various degrees of accuracy according to the requirements, setting, and expediency attending.

The more common and practical methods are presented in Part II, Open Channels, Chapters II to V, inclusive. The methods described in Chapters VI and VII are not ordinarily used in the large majority of irrigation water diversion and measurement installations, particularly by the smaller. Certain of these so-called special methods may well prove the most practical, expedient, accurate, and least costly under conditions which are not favorable to the more common or standard methods.

2. General Units of Measurement. Two kinds of units are used in the measurement of water: units of flow or discharge and units of volume.

Flow or discharge is defined as a rate, or the volume of water that passes a particular reference point in a unit of time. The units of flow at present employed in irrigation practice in the West are the miner's inch, and the second-foot.

The miner's inch (mi. in.) is not a definite unit, as it varies as to quantity in the various states. The following list of equivalents defines the miner's inch in the different western states:

21

[illegible]

(c) [illegible] acre-foot

[illegible]

An acre-foot [illegible] of water [illegible].

The unit of [illegible] irrigation [illegible] quantity [illegible]. Therefore, it is [illegible].

3. [illegible]. [illegible] the fact that the miner's inch [illegible] by the use of the second-feet as a unit, has a different value in different States, it is an undesirable unit of measure to use, and the Bureau of Reclamation has adopted the second-foot as the unit of measure where flow is considered. Owing to convenience of size and its particular application to land areas, the acre-foot has been adopted as the unit of measure where volume is considered independently of time.

4. Table 1. [illegible] contains the acre-foot equivalents of given second-foot discharges for stated lengths of time. It is designed to assist in [illegible] rates of flow in [illegible] or intervals [illegible] by field [illegible]. By means of this table the acre-foot equivalent of any second-foot discharge for [illegible] of time may be [illegible] directly [illegible] necessary [illegible].

An illustration follows: Suppose it is desired to ascertain how many acre-feet are represented by a discharge of 14.52 second-feet flowing for 2 hours and 15 minutes. From the table (remembering that the tabular values are multiplied by 10 or 100 by moving the decimal point one or two places to the right, respectively):

		Acre-feet
14	second-feet flowing 2 hours equals - - - - -	2.314
14	second-feet flowing 15 minutes equals - - - -	.289
0.52	second-feet flowing 2 hours equals - - - -	.086
0.52	second-feet flowing 15 minutes equals - - -	.011
14.52	second-feet flowing 2 hours and 15 minutes equals	2.700

5. Kinds of Measuring Devices. In the measurement of irrigation water the Bureau of Reclamation utilizes the following common methods and devices:

Weirs
Submerged orifices
Parshall flumes
Current meter gaging stations

Where there is sufficient available fall in a canal or channel, and the quantity of water to be measured is not too large, the most serviceable and economical measuring device that can be used is the weir; it is the simplest and the most accurate of all the more practical devices commonly used under favorable conditions. Where there is little available fall, the quantity of water small, and there is not too much floating debris, the submerged orifice is applicable. The Parshall flume may be used in lieu of either of the aforementioned methods to advantage in many cases. In addition to several favorable operating characteristic advantages the Parshall flume will accommodate discharges much larger than practicable with a weir. Where the quantity of water is large and the operating conditions and installation costs are not favorable for the utilization of the weir or Parshall flume, current-meter gaging stations may become the most practical.

In addition, the following methods or devices not commonly used in typical irrigation projects are utilized where adaptable to special field conditions:

Float method
Pitot tube
Salt-velocity method
Salt-dilution method
Color-velocity method
Calibrated sluices and gates
Venturi meter
Flow nozzles
Orfice meter
California pipe method
Current meter method for pipes
Calibrated water wheel and valves
Clausen - Pierce weir gage
Commercial meters

These methods and devices together with others less frequently used are discussed in Chapters VI and VII.

6. Accuracy of Computations. In the computation of the flow or discharge from the data gathered in the field from the measuring devices, accuracy is, of course, most desirable. However, the computations should not be carried out to a greater number of significant figures than the data justify. Doing so implies an accuracy which does not exist and may give results that are entirely misleading.

An illustration follows: Suppose it is desired to compute the discharge over a standard contracted rectangular weir using the formula, $Q = CLH^{3/2}$, where Q is the discharge in second-feet to be computed, C is 3.33, a constant for the weir, L is the observed length of the weir in feet and H is the observed head on the weir, in feet. If the observed length of the weir is 1.50 feet and the observed head is 0.41 feet the discharge would equal 3.33 x 1.50 x 0.2625 or 1.31 second-feet.

24

It may be stated in general that in any computation involving multiplication or division, in which one or more of the numbers is the result of observation, the answer should contain the same number of significant figures as is contained in the observed quantity having the fewest significant figures. In applying this rule it should be understood that the last significant figure in the answer is not necessarily correct, but represents merely the most probable value.

PART II - OPEN CHANNELS

CHAPTER II - WEIRS

7. Definition and Classification of Weirs. A weir may be defined as a notch of regular form through which water flows. In its simplest form it consists of a bulkhead of timber, concrete, sheet steel or of other fabrication having in its top edge a notched opening of fixed dimensions and shape through which a stream may flow. The notch is called a weir notch. Its bottom edge is called the crest and the depth of water passing over the crest is the head (as measured at a definite point upstream from the weir bulkhead). The horizontal distances from the ends of the crest to the sides of the canal or the side walls of the weir box are called the end contractions, and the vertical distance from the crest to the bottom of the canal or the floor of the weir box or the bed of the channel, is the bottom contraction. When these distances are great enough to cause the water to approach the weir notch at a low velocity, the weir is said to have complete contractions. However, when there is no distance from the side of the weir notch to the side walls of the weir box or channel, the contractions are said to be suppressed and the weir is said to be a suppressed weir.

The stilling basin upstream from the weir bulkhead is called the the weir pond. The sheet of water passing through the notch and falling over the weir crest is called the nappe. When the water surface downstream from the bulkhead is far enough below the crest so that air has free access completely around the nappe, the flow is said to be free; otherwise it is submerged.

The weirs generally employed for the measurement of irrigation water are the trapezoidal weir of the Cipolletti type, the rectangular weir and the 90-degree V-notch weir, as shown in figure 1.

Each of these types of weirs may again be divided into free weirs and submerged weirs as defined above; also each may be classed as

26

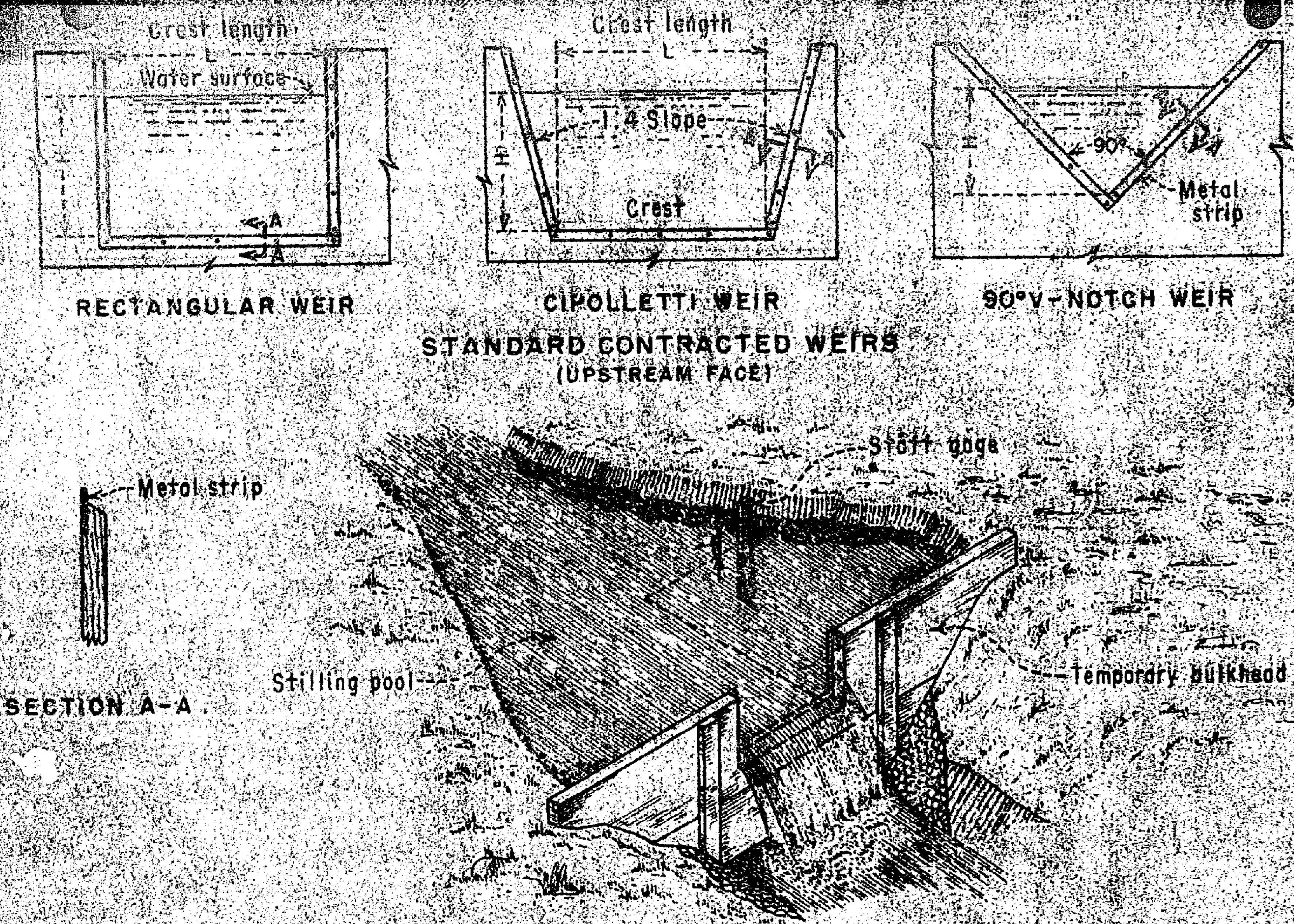


Figure 1. - Temporary bulkhead with contracted rectangular weir discharging at free flow. Alternate type weirs are shown above.

either suppressed or contracted weirs, as described earlier in this section. In this connection the common usage of the term "suppressed" applies to the rectangular weir. The suppressed rectangular weir is one with its sides coincident with the sides of the rectangular channel. Other types of suppressed weirs are not commonly used.

8. Types of Weirs Adopted. The types of weirs adopted by the Bureau of Reclamation for the measurement of irrigation water are:

(a) Sharp-crested contracted rectangular weir
(b) Sharp-crested suppressed rectangular weir
(c) Sharp-crested and sharp-sided Cipolletti weir
(d) Sharp-crested 90-degree V-notch weir

These four types of weirs will hereinafter be designated respectively as:

(a) The standard contracted rectangular weir
(b) The standard suppressed rectangular weir
(c) The standard Cipolletti weir
(d) The standard 90-degree V-notch weir

It is the intention of the Bureau to use these weirs without submergence, for greater accuracy, although there may be occasions where it will be necessary to permit submergence for short periods of time.

9. Definition of Setting for Standard Weirs.

(a) Standard contracted rectangular weir.

A standard contracted rectangular weir is a rectangular weir with its crest and sides so far removed, respectively, from the bottom and sides of the weir box or channel in which it is set, that the filaments of water are fully deflected from their normal course. This deflection is approximately the maximum deflection that would occur with the crest and sides of the weir at unlimited distances from the channel boundaries.

Extensive experiments on weirs and long experience with their use dictate that the following conditions are necessary for accurate measurement of flow with the standard contracted rectangular weir:

(1) The upstream side of the weir bulkhead should be smooth. The upstream side of the crest and side edges of the weir should be straight, sharp and smooth and flush with the bulkhead.

(2) The distance of the crest and sides of the weir, respectively, from the bottom and sides of the weir pond should preferably be not less than twice the depth of water on the weir, and in no case be less than 1 foot.

(3) The overflowing sheet should touch only the upstream edges of the crest and sides.

(4) Air should circulate freely both under and on the sides of the overflowing sheet.

(5) The upstream face of the weir should be vertical.

(6) The crest should be level from end to end.

(7) The sides should be truly vertical.

(8) The measurement of the head on the weir should be the difference in elevation between the weir crest and the water surface as measured at a point upstream from the weir of from 5 to 10 times the maximum head on the crest.

(9) The cross section of the leading channel (weir pond) should be at least 6 times that of the overflowing sheet at the weir crest for a length upstream of from 15 to 20 times the depth of the overflowing sheet.

(10) Corrections should be made for velocity of approach where appreciable errors are caused by neglecting the head due to it.

(b) <u>The standard suppressed rectangular weir.</u>

A standard suppressed rectangular weir is a rectangular weir with its crest consisting of a thin plate so far removed from the bottom of the leading channel or weir pond as to cause the filaments of water to be fully deflected from their normal course, and with its sides coincident with the sides of the leading channel, so that there is no change in direction laterally of the filaments of water passing through the weir.

All conditions for accuracy of measurements for this type of weir are identical with those of the contracted rectangular weir, except those relating to side contraction.

In the suppressed weir the sides of the leading channel should be coincident with the sides of the weir, and the overfalling sheet should not be allowed to expand laterally immediately downstream from the weir. A suppressed weir in a flume drop is illustrated in figure 2.

Special care must be taken with this type of weir to secure the proper aeration beneath the overflowing sheet below the crest.

(c) The standard Cipolletti Weir.

A standard Cipolletti weir is a trapezoidal weir with its crest and sides, consisting of a thin plate, so far removed from the bottom and sides of the leading channel as to cause the filaments of water to be deflected from their normal course and with its sides sloping outward as they rise in a ratio of 1 to 4.

While the Cipolletti weir is necessarily a contracted weir, and should be so considered as far as requirements of installation are concerned, yet, in discharge effect, it is a suppressed weir. This is due to the fact that Cipolletti in his formula has allowed for the reducing effect in the discharge due to end contractions by making the sides of the weir sufficiently sloping to overcome this effect.

All conditions for accuracy stated for the standard contracted rectangular weir apply to the Cipolletti weir except that of the slope of the sides. A Cipolletti weir in a canal drop is illustrated in figure 2A.

(d) The standard 90-degree V-notch weir.

A standard ninety-degree V-notch weir is a triangular shaped weir whose crest consists of a thin plate, the sides of the notch being 45 degrees from the vertical and 90 degrees with respect to each other.

This weir is a contracted weir and all conditions for accuracy stated for the standard contracted rectangular weir apply to the standard 90-degree V-notch weir except those of the crest and sides.

Because the V-notch weir has no crest length the head required for a small flow through it is greater than the head required for

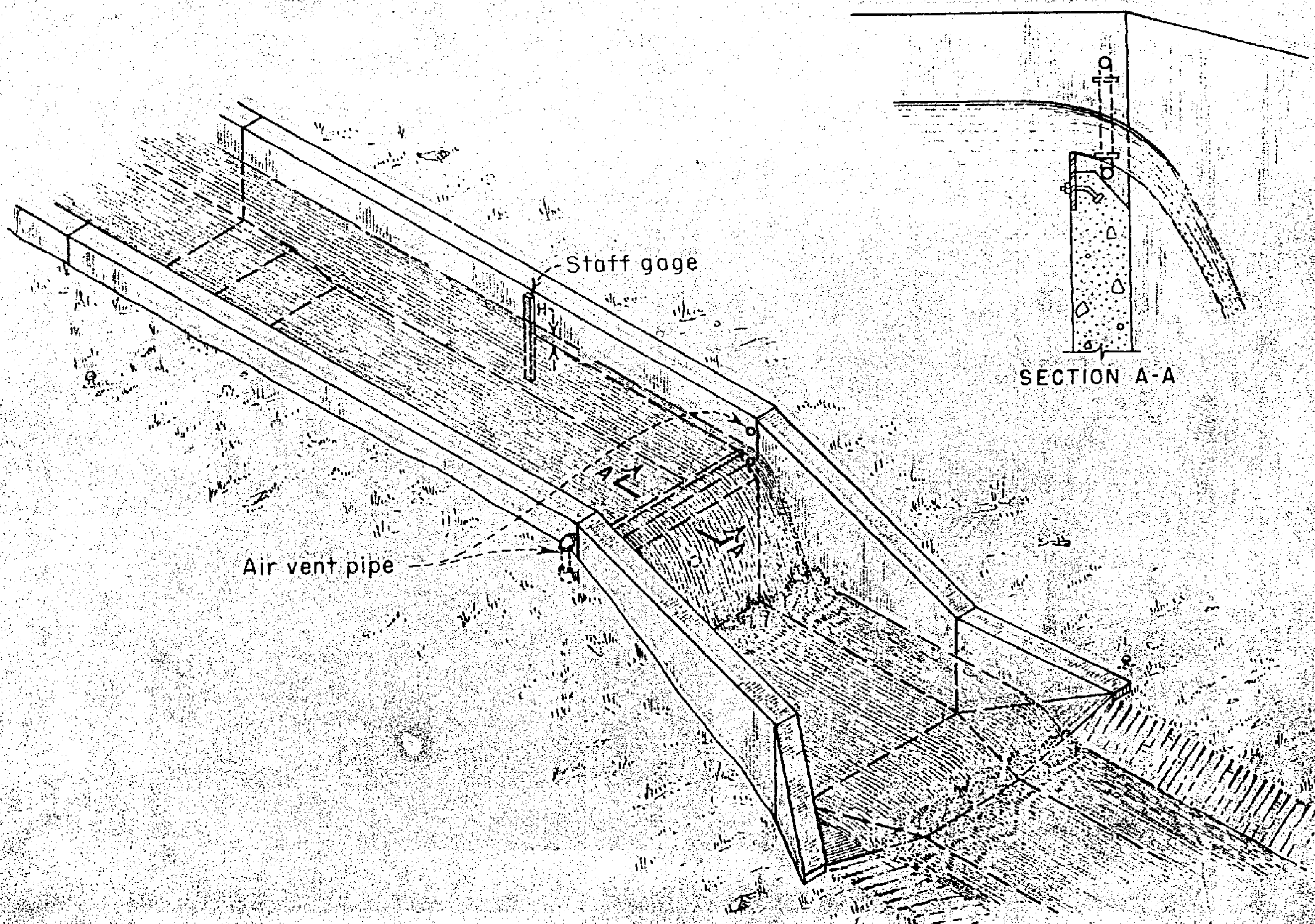


Figure 2. - Typical suppressed weir in flume drop

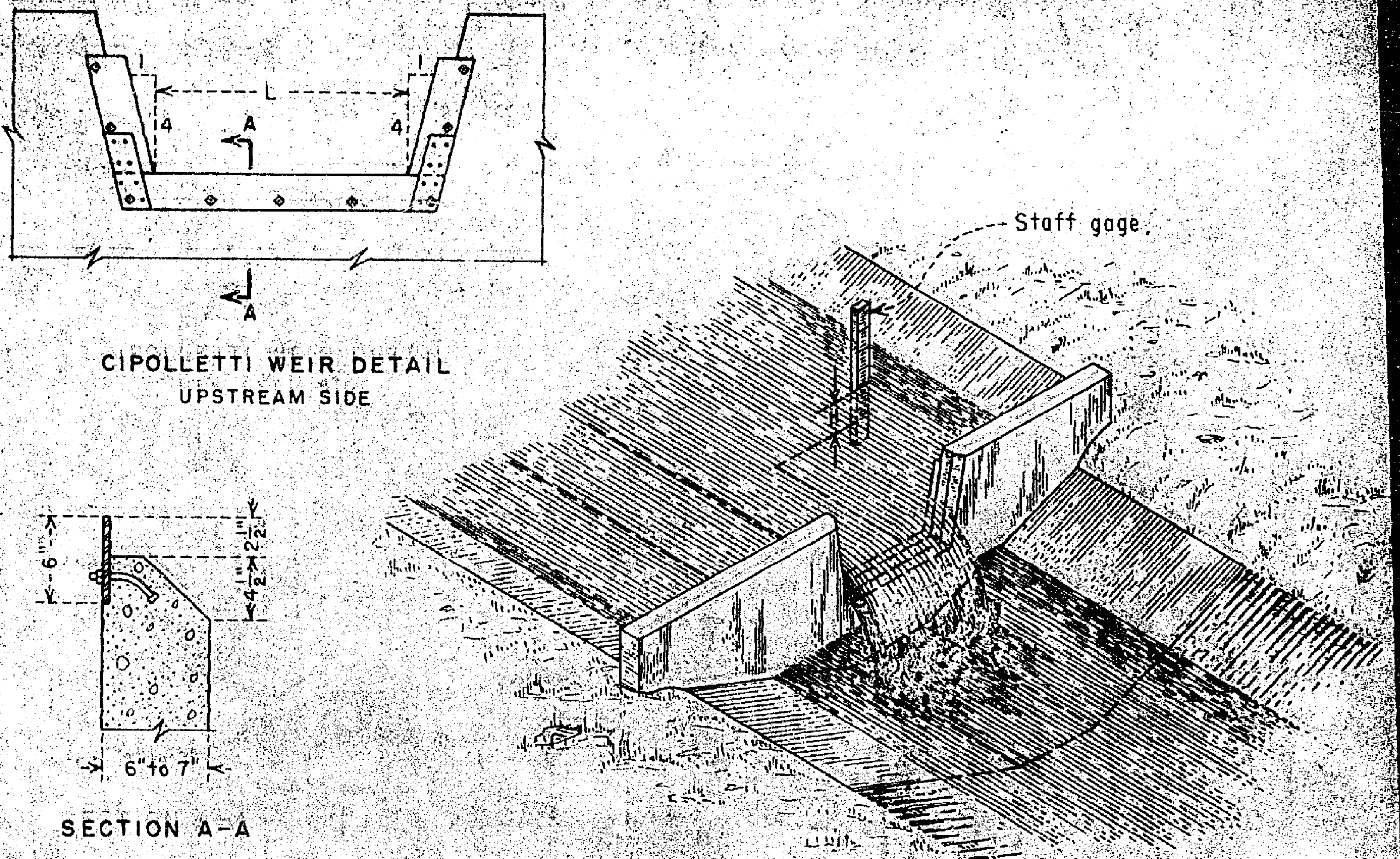


Figure 21. - Permanent type bulkhead in canal. Cipolletti weir discharging with free flow conditions.

each of the other type weirs. However, this is an advantage for small discharges in that the nappe will spring free of the crest of the V-notch weir where it would cling to the crest of another type weir making the measurement worthless. Therefore, the V-notch weir is especially useful for small discharges up to two or three second-feet. It has been found that the Cipolletti and rectangular weirs in the order of six inches in length are not as accurate and sensitive as the V-notch weir for small flows and therefore are not recommended where the V-notch weir may be used for measuring such relatively small flows.

With the criteria cited in this section well in mind the irrigation operator may construct weirs either temporary or permanent capable of measuring the flow of irrigation water where weirs are the most practicable device.

10. Construction and Installation of Weirs. As a temporary expedient in making approximate measurements of small flows in earthen channels, a portable weir may be used. This may be made from a piece of stiff sheet metal cut in a semicircle approximately the shape of the cross section of the channel but somewhat larger, with a weir notch cut in the top edge. In setting this weir, it is only necessary to force the metal plate firmly into the soft bottom and sides of the channel, normal to the direction of flow, and then adjust the crest to a level position by tapping down the higher side.

As a temporary expedient in making approximate measurements of small discharges in ditches a temporary weir bulkhead and weir such as illustrated in figure 1 may be used. The weir notch cut into the top of the bulkhead should be cut about three inches longer than the crest length to allow for the insertion of angle irons or metal strips to form the sharp crest and sides of the weir and to insure that the nappe will spring clear of the bulkhead.

A portable weir made from a piece of stiff sheetmetal cut roughly in a semicircle approximating the shape of the cross-section of the ditch, but somewhat larger, may be used. In setting this weir it is only necessary to force the metal sheet into the soft ground far enough to insure its stability and to level the crest. The weir plate must be normal to the direction of flow and in a vertical position.

For reasons of instability simple bulkheads described above would prove impracticable. To overcome this difficulty the bulkhead may be built inside of and integral with a wooden or concrete "weir box" similar to that shown in figure 3.

In the case of earth channels the weir box should in all cases extend downstream from the weir crest far enough to still the water before it passes back into the channel below. The floor of the downstream portion of the box may well be slightly depressed to form a stilling pool.

In the special case of the standard suppressed rectangular weir, the sides of the downstream portion of the box should be coincident with the overflowsheet, or nappe. In the case of the rectangular contracted weir, the Cipolletti weir and the V-notch weir they should be set back slightly from the sides of the weir crest.

In suppressed weirs a pipe or other means should be provided for admitting air to the underside of the over-falling sheet in order to assume accurate contraction.

Table 2 taken from Farmers Bulletin 1683, Department of Agriculture, gives the sizes of weirs best adapted to measuring the flow of water from ½ to 60 second-feet. Dimensions of a structure suitable for the contracted rectangular, Cipolletti and V-notch weirs are given in this table. The dimensions given in table 2 are considered to be the minimum required for reasonable accuracy of weir measurements.

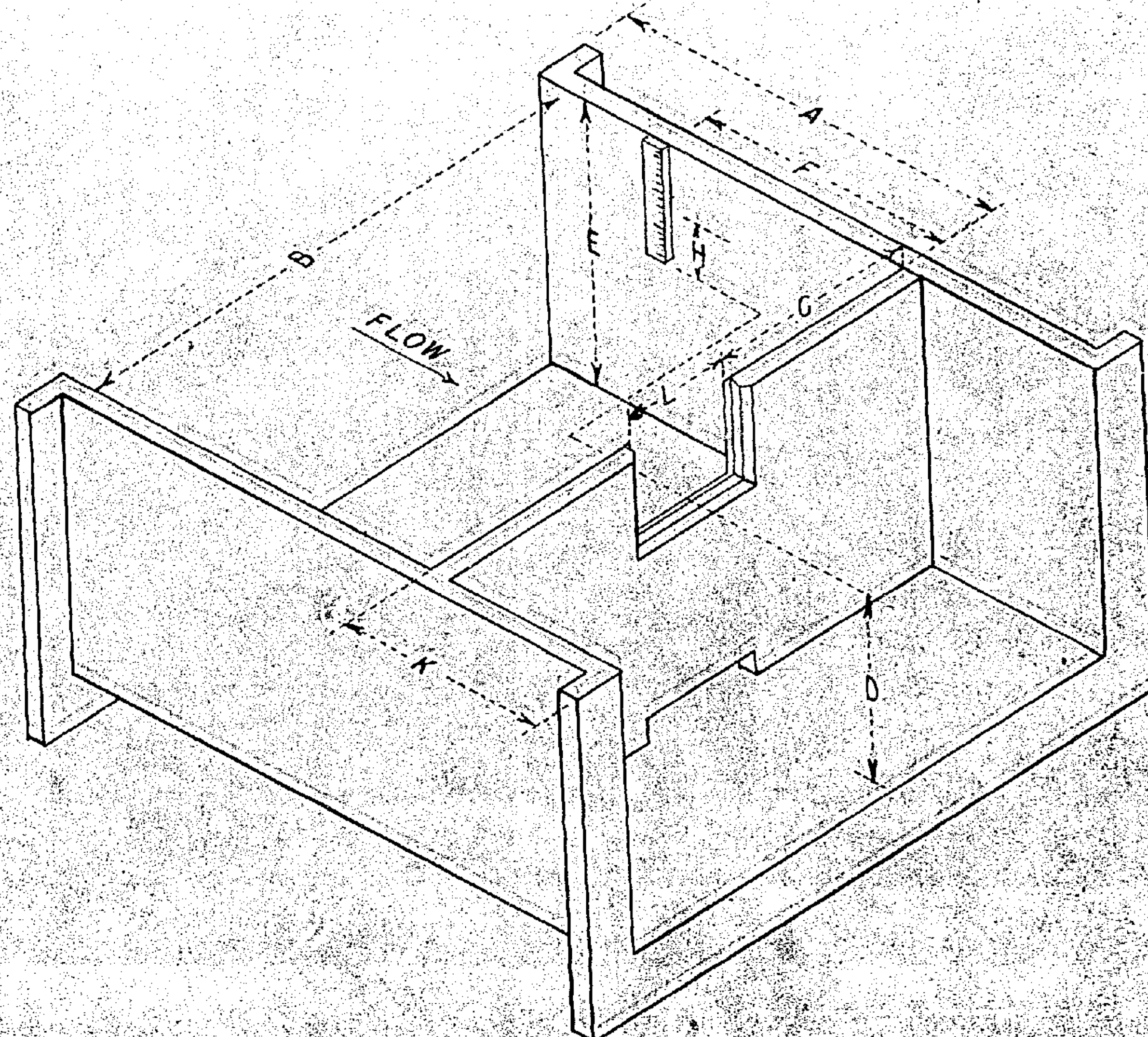


Figure 3. - Weir box showing minimum dimensions and proportions

TABLE 2 Weir-box dimensions for rectangular, Cipolletti, and 90° V-notch weirs

(Letters refer to dimensions, fig. 3)

RECTANGULAR AND CIPOLLETTI WEIRS

Discharge (second-feet)	H Maximum head	L Length of weir crest	A Length of box above weir notch	K Length of box below weir notch	B Total width of box	E[1] Total depth of box	C Distance from end of crest to side of box	Distance from crest to bottom of box	F Gage distance
	feet	feet	feet	feet	feet	feet	feet	feet	feet
¼ to 3	1.0	1	6	2	3	3	1	1¼	4
2 to 5	1.1	1½	7	3	4	3	1¼	1¼	4½
4 to 8	1.2	2	8	4	5	3½	1½	1-3/4	5
6 to 14	1.3	3	9	5	7	4	2	2	5½
10 to 22	1.5	4	10	6	9	4	2½	2	6
15 to 25	1.5	6	12	6	11½	4½	2-3/4	2½	6
20 to 50	1.5	8	16	8	14	4-3/4	3	2-3/4	8
25 to 60	1.5	10	20	8	17	5	3½	3	8

90° V- NOTCH WEIR

½ to 2½	1.00	--	6	2	5	3	--	1½	4
2 to 4-1/3	1.25	--	6½	3	6½	3¼	--	1½	5

1 This distance allows for about 6 inches freeboard above highest water level in weir box.

36

For best operating conditions, the weir structure should be set in a straight reach of the channel, normal to the line of flow. It must be certain that the weir crest is level and the sides of the weir are vertical and the weir bulkhead is vertical or plumb.

Adequate cut-offwalls well tamped in place should be used on the weir structure to prevent erosion causing undermining or washing around the structure. The banks and bottom of the channel should be trimmed to conform approximately to the shape and size of the box for a distance of 15 to 20 feet upstream.

The weir box gradually accumulates sand and silt to such an extent that discharge measurements may be considerably in error. For cleaning the weir box, an opening large enough for silt and sand deposits to be washed downstream through may be provided in the weir bulkhead at the floor line beneath the weir notch, as shown in figure 3. This sluice way should be provided with a suitable cover.

Frequent cleaning and trimming of the channel and weir box structure with shovel or scraper will be necessary to maintain proper weir operating conditions.

The Bureau of Reclamation has adopted a series of standard designs for concrete weir drops for use in canals, lined or unlined. The weir designs fall into three sizes:

Concrete Weir - Maximum capacity, 3 sec. ft., Dwg. No. 40-D-2070

Concrete Weir - Capacity 3 to 35 sec. ft., Dwg. No. 40-D-2071

Concrete Weir - Capacity 35 to 70 sec. ft., Dwg. No. 40-D-2072

11. Discharge Measurements. The discharge in second-feet over the crest of a standard contracted rectangular weir, a standard suppressed rectangular weir, and a standard Cipolletti weir is determined by the head (H) in feet and the length (l) in feet. In the case of the standard 90-degree V-notch weir the discharge is determined directly by the head on the bottom of the V-notch.

As the stream passes over the weir the surface curves downward. This curved surface, or drawdown, extends upstream a short distance from the weir notch. The head (H) must be measured from a point on

37

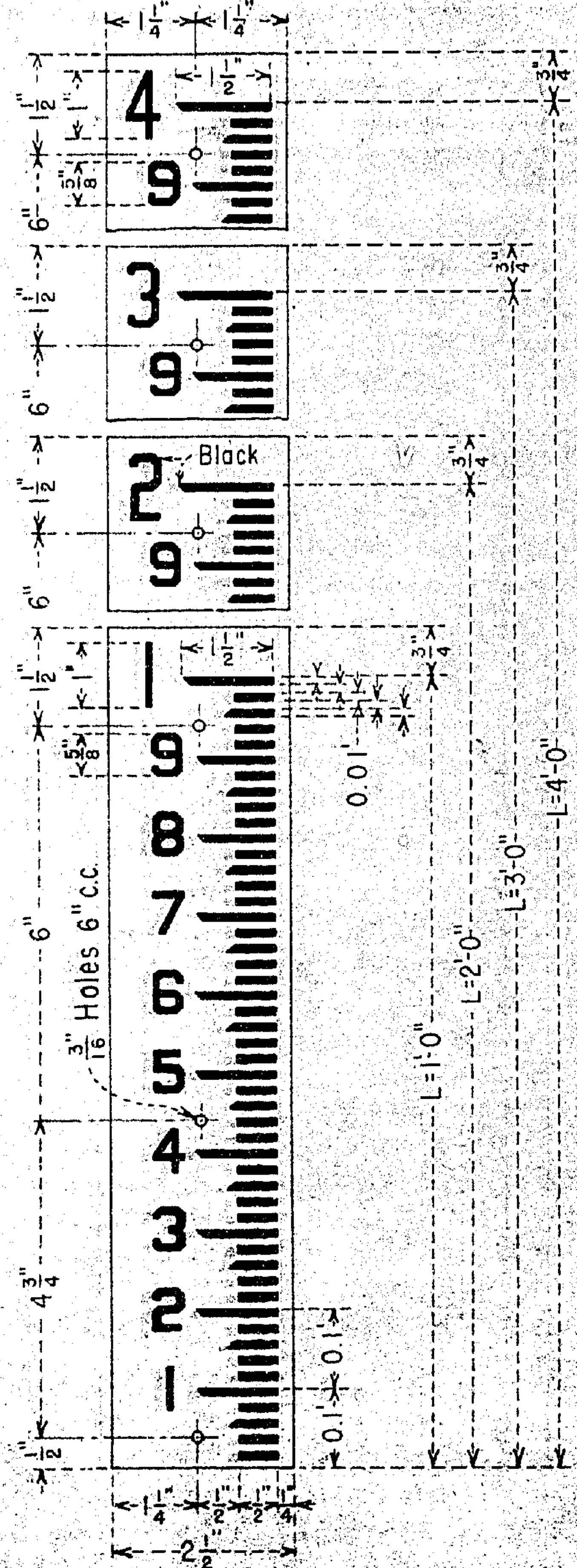
the water surface of the weir pond beyond the effect of the drawdown. It has been found that this distance should be at least from 5 to 10 times the maximum head on the weir. The same gage point should be used for lesser discharges. A staff gage having a graduated scale on which the zero end is placed at the same elevation as the weir crest, is usually attached to the inside face of the weir box in a vertical position at the gage point. Figure 4 illustrates a standard staff gage adopted by the Bureau of Reclamation. Stilling wells described in Section 31 may be used for more accurate reading of the head.

Where a simple weir is placed across the channel, a flat top stake or post may be driven into the bed of the weir pond, at the proper distance back from the weir, until its top is at the same elevation as the crest of the weir. The depth of the water over this post will be the head on the crest. The post should be placed beyond the effect of the drawdown and close enough to the bank of the channel to be reached easily.

After the head, or depth of water on the crest of the weir, is determined the rate of flow or discharge may be found by referring to the tables described in succeeding paragraphs. These tables are for free-flow conditions and applicable only to weirs installed according to the criteria set forth in the preceding paragraphs in regard to standard contracted weirs. Many of the values shown in these tables were determined experimentally. The remainder were computed from the well known formulas discussed in the later sections.

12. Care of Weirs. The weir and weir pool should be freed from weeds and trash at each round of the canal rider and the weir pool should be cleaned of silt from time to time as it accumulates. The level of the crest should be checked periodically and should also be checked with reference to the elevation of the zero of the gage. Inspection should be made to determine whether there is leakage around the weir, and in the event of such leakage, the structure should be immediately repuddled and carefully rechecked to see that the weir is level and at the elevation of the zero of the gage.

13. Formulas for Standard Contracted Rectangular Weir. Two widely used formulas for computing the discharges over standard contracted rectangular weirs are those of Hamilton Smith and J. B. Francis.



NOTES

Gages to be made of number 16 U.S. Gage metal and to be covered with a substantial thickness of porcelain enamel.

The face of the gage shall be white and all numerals and graduations shall be black.

Graduations shall be sharp and accurate to the dimensions shown.

The length "L" shall be as given in the schedule. In case a greater length than 4'-0" is required the details shall be similar to details shown for shorter lengths.

Figure 4. — Standard scale gage

The formulas proposed by Hamilton Smith require the use of coefficients of discharge varying with the head of the water of the weir, and also the length of the weir, which makes them somewhat inconvenient, although they are accurate for the ranges of coefficients usually given. The Francis formula for this type of weir, operating under favorable conditions as prescribed in preceding paragraphs, and with negligible velocity of approach is as follows:

$$Q = 3.33 H^{3/2} (L - 0.2H) \qquad (1)$$

and with sizeable velocity of approach is as follows:

$$Q' = 3.33 \left[(H + h)^{3/2} - h^{3/2})\right] (L - 0.2H) \qquad (2)$$

where

Q = discharge in sec.-ft. neglecting velocity of approach

Q' = discharge in sec.-ft. considering velocity of approach

L = the length of weir, in feet

H = head on the weir in feet, and

h = head, in feet, due to the velocity of approach = $\frac{V^2}{2g}$

It will benoted that Francis formulas contain constant discharge coefficients which make computations by them easy without the use of tables. The Francis experiments were made on comparatively large weirs, most of them 10 feet long, with heads ranging from 0.4 to 1.6 feet, so that the formulas apply particularly to such weirs rather than to short weirs with low heads. Experiments on 6-inch, 1-foot, and 3-foot weirs on the Boise Project, Idaho, show that these formulas apply fairly well to shorter weirs, provided the head of water on the weir is not greater than about one-third the length of the weir. For a ratio of depth to length greater than 1/3, the actual discharges exceed those given by the formulas by an amount which increases gradually from 0 percent for a ratio of 1/3 to about 30 percent for a ratio of 1/1.

Table 3 (see section 84) provides $H^{3/2}$, $h^{3/2}$, and $(H+h)^{3/2}$ for convenience in computing discharge with the formulas described in this section.

14. Table 4 - Discharge of Standard Contracted Rectangular Weirs. (see section 84) This table was compiled for convenience and to obviate the necessity of solving the Francis formula for discharge for each weir

head reading. It contains discharges in second-feet for standard contracted rectangular weirs without velocity of approach, computed from the Francis formula for the lengths and heads ordinarily used in measuring small quantities of irrigation water; except that for the 6-inch, 1-foot, 2-foot, and 3-foot weirs, for heads greater than 1/3 the crest length, the experimental values obtained on the Boise Project have been used instead of the values given by the formula.

This table may, therefore, be considered to give fairly accurate discharge for weirs of the above stated lengths and for weirs of other lengths where the head does not exceed 1/3 the length of the weir crest.

The method of using the table is apparent.

15. Formulas for Standard Suppressed Rectangular Weirs. The two principal formulas used for computing the discharge of the standard suppressed rectangular weirs are also those of Smith and Francis. In the Smith formulas for suppressed weirs, as for contracted weirs, the coefficients of discharge vary with the head on the weir and with the length of the weir, so these formulas are not convenient for computations without the use of tables of coefficients. The law of these variations for the two types of weirs is different, so it is necessary to provide a separate table for each.

The Francis formula for the standard suppressed rectangular weir, without velocity of approach, is as follows:

$$Q = 3.33 \, L \, H^{3/2} \qquad (3)$$

and with velocity of approach is as follows:

$$Q' = 3.33 \left((H + h)^{3/2} - h^{3/2} \right) L \qquad (4)$$

In these formulas the letters have the same significance as in those for contracted rectangular weirs discussed in section 13. The coefficient of discharge was obtained by Francis from the same general set of experiments as those stated for the contracted rectangular weir. No extensive tests have been made to determine the applicability of these formulas to weirs less than 4 feet in length. The accompanying table 5 gives discharges for as low as 0.01 ft. head. However, as a practical matter, heads much less than 0.2 ft. will not be found possible to observe, because for the particularly low heads the nappe will not spring free of the crest, under ordinary field conditions.

16. Table 5. (see section 84) Discharge of Standard Suppressed Rectangular Weir. This table contains discharges in second-feet for standard suppressed rectangular weirs without velocity of approach, computed from the Francis formula for the lengths and heads commonly used in measuring small quantities of irrigation water.

Theoretically the formula for the standard Cipolletti weir without velocity of approach should be the same as the Francis formula for the standard suppressed rectangular weir. Cipolletti, from his experiments, however, increased the Francis coefficient by about 1 percent.

It has been common accepted practice for years to use the formula for the discharge of the standard Cipolletti weir for computation of discharge for the standard suppressed rectangular.

In recent years the simplified form of the Rehbock formula has been used by office engineers interested in irrigation water measurement. However, this formula, together with the Francis, Cipolletti, V-notch weir formula are all too complicated to have any practical value for the layman. Therefore, the tables are provided for the ready determination of discharge from field data. Only in unusual circumstances should it be necessary to use the formulas cited herein.

17. Formulas for Standard Cipolletti Weir. As pointed out heretofore the Cipolletti weir is by definition a contracted weir and must be installed as such to get correct and consistent discharge measurements. However, Cipolletti has allowed in his formula for the reducing effect in the discharge due to end contractions by making the sides of the weir sufficiently sloping to overcome the effect of contraction. Therefore, theoretically, the formula for the standard Cipolletti weir without velocity of approach would be expected to be identical to the Francis formula for the standard suppressed weir.

Cipolletti, however, from his experiments increased the Francis coefficient by about 1 percent, so that his formula, without velocity of approach, is as follows:

$$Q = 3.367\ LH^{3/2} \qquad (5)$$

The discharge for this weir with velocity of approach may be obtained from the following formula:

$$Q' = 3.367\ L\ (H + 1.5\ h)^{3/2} \qquad (6)$$

In these formulas the letters have the same significance as in the preceding formules. The correction for velocity of approach may be applied, as in the Francis formula also, with fair results.

18. Table 6 (See section 84) Discharge of Standard Cipolletti Weir. This table contains discharges in second-feet for standard Cipolletti weirs without velocity of approach, computed from the Cipolletti formula for the heads and lengths of weirs generally used in measuring small quantities of irrigation water; except that for the 6-inch, 1-foot, 2-foot, and 3-foot weirs, for heads greater than one-third the crest length, the discharges have been taken from experiments made on the Boise Project. The data should, therefore, be considered fairly accurate for weirs of the above stated lengths for all heads given in the table and for weirs of other lengths for heads not over one-third the crest length.

19. Formulas for Standard 90-degree Contracted V-notch Weir. There are several well known formulas used to compute the discharge over 90-degree V-notch weirs, the most commonly used of which are the Cone formula and the Thomson formula, in the field of irrigation.

The Cone formula is considered among authorities to be the most reliable for small weirs and for conditions generally encountered in measuring water for irrigation. The formula is as follows:

$$Q = 2.49\ H^{2.48}$$

where

Q = discharge over weir in second-feet, and

H = head on the weir, in feet

V-notch weirs are not ordinarily appreciably affected by velocity of approach. If the weir is installed with complete contraction the velocity of approach will be low.

20. <u>Table 7 - Discharge over 90-degree V-notch Weir.</u> This table was compiled for convenience and to obviate the necessity of solving the Cone formula for each weir head reading. It contains discharges in second-feet for the standard 90-degree contracted V-notch weir without velocity of approach computed from the Cone formula for a range of heads ordinarily used in measuring small quantities of water.

TABLE 7 - DISCHARGE TABLE FOR 90° V-NOTCH WEIR

Head in feet	Discharge in second-feet	Head in feet	Discharge in second-feet	Head in feet	Discharge in second-feet
0.20	0.046	0.55	0.564	0.90	1.92
.21	.052	.56	.590	.91	1.97
.22	.058	.57	.617	.92	2.02
.23	.065	.58	.644	.93	2.08
.24	.072	.59	.672	.94	2.13
.25	.080	.60	.700	.95	2.19
.26	.088	.61	.730	.96	2.25
.27	.096	.62	.760	.97	2.31
.28	.106	.63	.790	.98	2.37
.29	.115	.64	.822	.99	2.43
.30	.125	.65	.854	1.00	2.49
.31	.136	.66	.887	1.01	2.55
.32	.147	.67	.921	1.02	2.61
.33	.159	.68	.955	1.03	2.68
.34	.171	.69	.991	1.04	2.74
.35	.184	.70	1.03	1.05	2.81
.36	.197	.71	1.06	1.06	2.87
.37	.211	.72	1.10	1.07	2.94
.38	.226	.73	1.14	1.08	3.01
.39	.240	.74	1.18	1.09	3.08
.40	.256	.75	1.22	1.10	3.15
.41	.272	.76	1.26	1.11	3.22
.42	.289	.77	1.30	1.12	3.30
.43	.306	.78	1.34	1.13	3.37
.44	.324	.79	1.39	1.14	3.44
.45	.343	.80	1.43	1.15	3.52
.46	.362	.81	1.48	1.16	3.59
.47	.382	.82	1.52	1.17	3.67
.48	.403	.83	1.57	1.18	3.75
.49	.424	.84	1.61	1.19	3.83
.50	.445	.85	1.66	1.20	3.91
.51	.468	.86	1.71	1.21	3.99
.52	.491	.87	1.76	1.22	4.07
.53	.515	.88	1.81	1.23	4.16
.54	.539	.89	1.86	1.24	4.24
				1.25	4.33

21. Velocity of Approach in Weir Measurements. So far as practicable weirs should be installed and maintained so as to make the velocity of approach negligible; but where it is impracticable to do this appropriate corrections should be made.

Such corrections for the Francis formulas are difficult to make without the use of tables providing percentages of increase to apply to the computed discharges. In the formula given for use with the Cipolletti weir the correction can be applied to the measured head directly and the proper discharge readily obtained, or the discharge can be obtained as indicated by the Francis method and use of tables.

It should be borne in mind that moderate velocities of approach with low heads on the weir produce large errors, whereas comparatively high velocities of approach with large heads on the weir produce relatively small errors.

The velocity of approach may be computed from the following formula:

$$v = Q \div A \qquad (7)$$

where v = velocity of approach in feet per second

Q = discharge, in second-feet, and

A = cross-section area of the leading channel or weir pond in square feet

Q, the discharge may be computed from the appropriate weir formula or determined from tables without the velocity of approach, with sufficient accuracy for determining v for ordinary cases. Successive approximations may be used to determine v to any desired degree of accuracy for special cases.

Having determined the value of v, the velocity of approach head may be computed from the following formula:

$$h = 0.0156\, v^2 \qquad (8)$$

After h has been computed by formula (8), the effective head D, on the weir can be computed from the measured head, H, by means of the following formula:

$$D = \left((H + h)^{3/2} - h^{3/2} \right)^{2/3} \qquad (9)$$

in which H and h have the same significance as in preceding formulas, and D is the effective head due to the measured head and the velocity of approach. The weir discharge is then given by the proper formula for each type of weir as hereinbefore given.

For any type of weir, if the Francis method of correcting for velocity of approach is used by comparing formula (2) to (1), or formula (4) to formula (3), it is seen that the increased discharge with velocity of approach bears to the discharge for the same weir and head without velocity of approach the ratio shown in the following formula:

$$\frac{Q'}{Q} = \frac{D^{3/2}}{H^{3/2}} = C$$

in which Q', Q, H, and D have the same significence as in preceding formulas and C is a ratio varying with H and the velocity of approach. It is seen that C applied as a coefficient to Q will give Q'.

22. Table 8 (See section 84) Coefficients C to Be Applied to a Discharge Taken From Table 4, 5, 6 for a Head, H, to Determine the Discharge for the Same Weir with Velocity of Approach v. When there is considerable velocity of approach, corrections can be made by means of this table. First the velocity of approach should be computed as described in section 21. The discharge without velocity of approach should then be taken from table 4, 5, or 6 and multiplied by the coefficient given in table 8.

Illustration: Suppose it is desired to find the discharge of a standard Cipolletti weir with a crest length of 4 feet under a measured head of 1 foot and when there is a mean velocity of approach determined to be 1.5 feet per second. By table 6 the discharge without velocity of approach is 13.5 second-feet. From table 8, for a velocity of approach of 1.5 feet per second and with a head, H, of 1 foot, the coefficient is 1.047. Then 13.5 x 1.047 = 14.1 second-feet discharge with velocity of approach.

23. Submergence of Weirs. Accurate measurement cannot be made of submerged weir discharge, because of lack of extensive accurate experiments for determining the discharge coefficient. Practically all of the older experiments on submerged weirs were on suppressed rectangular ones. Clemens Herschel, from a discussion of these

experiments, derived a formula for computing discharges of such weirs. The Herschel formula is as follows:

$$Q1 = 3.33\, L(nH)^{3/2} \qquad (11)$$

where

L = length of weir in feet

H = measured head on the weir in feet

Q1 = discharge of second-feet with submergence,

and n = a factor of correction taken from a table for various values of the rates of submergence

The ratio of submergence is d ÷ H, where d = downstream head in feet, and H = upstream head in feet.

Limited experiments have been made on submerged contracted weirs by J. C. Stevens, on the Yakima Project of the Bureau. These experiments were considered and combined by Stevens with the older ones and a diagram prepared for determining the discharges of submerged weirs, both contracted and suppressed, from appropriate tables of free weirs.

These results differ only slightly from those of Herschel, so it may be roughly considered that Herschel's coefficients apply approximately to contracted as well as to suppressed weirs.

It should be pointed out, however, that the discharge measurements on submerged weirs are reliable to an approximate degree only when the depth of the stream below the weir is relatively large both upstream and downstream from the weir.

In Herschel's formula the coefficient n is applied to the observed head above the weir crest, on the upstream side. By comparing formula (11) to formula (3), the corresponding formula without submergence, it is seen that according to Herschel's formula the discharge of a submerged weir bears to that of a free weir with the same length and head the ratio shown in the following formula:

$$\frac{Q1}{Q} = \frac{(nH)^{3/2}}{H^{3/2}} = C' \qquad (12)$$

in which Q, Q1, H and n have the same significance as in preceding formulas and C' is a ratio varying with n or with the ratio of submergence. C' applied as a coefficient to Q will give Q_1.

24. Table 9 (See section 84) Coefficients C' to be Applied to a Discharge Given by Table 4, 5, or 6 for a Head H to Give Discharge of Same Weir Submerged, Computed from the Formula $C' = \frac{Q1}{Q} = \frac{(nH)^{3/2}}{H^{3/2}}$.

These coefficients will give approximate results at best and cannot be relied upon for a high degree of accuracy in any case. To obtain the discharge of a submerged weir by means of these coefficients, first the discharge of the same weir, free, should be taken from tables 4, 5, or 6 for the head on the upstream side of the weir and this discharge then multiplied by the proper coefficient obtained from table 9.

An illustration follows: Suppose it is desired to find the discharge over a submerged standard Cipolletti weir with a crest length of 3 feet when the head on the upstream side is found to be 1.32 feet and the head on the downstream side of the weir 0.33 foot. By table 6, the discharge of the same weir, free, under the same head, is 15.7 second-feet. The ratio $d \div H = 0.33 \div 1.32 = 0.25$, for which table 9 gives a coefficient of 0.958. The product, $15.7 \times 0.958 = 15$ second-feet, the discharge of the weir, submerged.

25. The Farmers' Short Box Measuring Flume. (1) The U. S. Department of Agriculture has run a series of calibration tests on the "farmers' short-box measuring flume" to make possible the successful use in the distribution of irrigation water of the structures of this type already installed.

The accuracy of the device is sufficient for ordinary requirements but it is not to be recommended in preferance to the standard type weirs or Parshall flume.

Figure 5 along with table 10 gives the dimensions and details of the flume calibrated.

Table 11 (See section 84) provides means of determining the discharge, readily obviating the necessity of using the cumbersome discharge formulas which follow:

$$Q = \frac{3.566}{(P-0.300)^{0.0164}} LH^{1.525} \qquad (13)$$

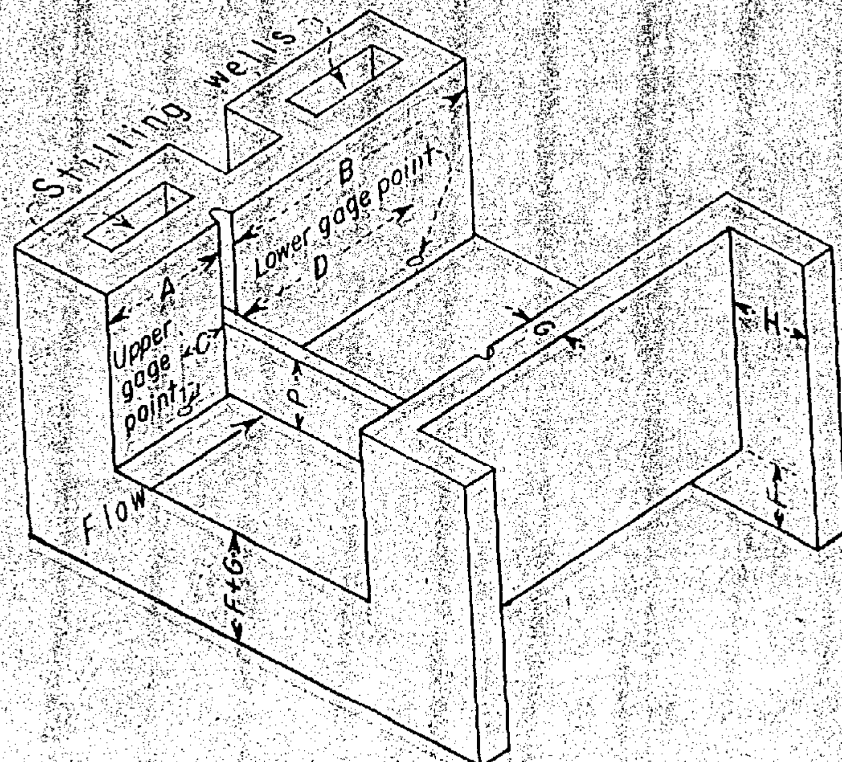


Figure 5. - Farmers short-box measuring flume

where Q = discharge in second-feet

P = height of weir in feet

L = width of flume (length of weir) in feet

and H = head, in feet, measured at the upper gage point

For submerged flow,

$$Q = \frac{4.12\ Hd^{0.418}(P-0.300)^{0.0605}}{P^{0.170}}\ LHa^{\frac{1.37\ Hd^{0.091}}{P^{0.128}}} \qquad (14)$$

where Q = discharge in second-feet

P = height of weir in feet

L = width of flume in feet

Ha = head, in feet, measured at upper gage point

and Hd = difference of head in feet between the upper and lower head

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(1) Department Bulletin 1110, U.S.D.A. Oct. 1922 "The Farmers Short Box Measuring Flume" By Carl Rohwer, Irrigation Engineer.

Formulas 13 and 14 are empirical formulas based on the calibration of 1-, 2-, 3-, and 4-foot flumes with 4-, 8-, 12-, and 16-inch weirs for various heads and differences of heads. They should not be used for larger or smaller flumes and weirs, nor for heads and differences of head beyond the limits of the experimental data. These limiting heads and differences of head are given in the tables computed from the formulas.

The tests showed that submerged conditions should be avoided if possible. For free-flow conditions, the gage height may be measured either on the crest of the weir, or 1 foot upstream from it. Care should be taken not to confuse the readings taken at the different points when using the discharge tables.

For submerged conditions, both the upstream and the downstream heads must be measured. On account of the disturbed condition of the water, it is recommended that, in order to increase the accuracy, the heads be measured in stilling wells placed outside the flume.

TABLE 10 - STANDARD DIMENSIONS FOR FARMERS' SHORT-BOX MEASURING FLUME

Size of Weir	Capacity of Weir	A Length of box above weir bulkhead	B Length of box below weir bulkhead	C Distance from weir bulkhead to upper gage	D Distance from weir bulkhead to lower gage	E Depth of flume	F Depth of Cut-off Wall	G Thickness of walls and floors	H Length of Wing Walls	L Length of Weir Crest	P Height of Crest
Feet	Sec-ft	ft.	ft.	ft.	ft.	ft.	ft.	inches	ft.	ft.	ft.
1	0.3 to 3.5	2	2.5	1	2	(1)	0.5	4	0.5	1	(2)
1.5	0.5 to 5	2	2.5	1	2	(1)	0.5	4	0.5	1.5	(2)
2	0.7 to 7	2	3.0	1	2	(1)	0.5	4	0.5	2	(2)
3	1.0 to 10	2	3.5	1	2	(1)	1	6	1	3	(2)
4	1.5 to 14	2	4.0	1	2	(1)	1	6	1	4	(2)

(1) The distance E depends on the height of P and the capacity required.

(2) The height of the crest P depends on the fall available in the lateral.

CHAPTER III - PARSHALL FLUMES

26. <u>General description</u>. Much of the descriptive matter of this chapter on Parshall flumes, large and small in size, has been extracted directly from Bulletins 386 and 423 of the Colorado Agricultural Experiment Station, Fort Collins, Colorado.

The Parshall flume, formerly called the improved Venturi flume, is a specially constructed measuring flume, so designed that the flowing water, for unsubmerged tail-water conditions, is forced to pass through critical depth within the structure thus providing a means by which a determination of the amount of water passing can be made from a single depth measurement.

It consists of a structure of wood, metal, or concrete which contracts the channel to a throat section and then expands it, both by dropping the bottom and widening the sides, so as to produce a hydraulic jump.

The size of the Parshall flume is determined by the width of the throat section. A one-foot flume, for example, is a flume whose throat width is one foot.

There are three groups of flume sizes and proportions; one group consists of the 3-, 6-, and 9-inch (throat width) size; another group consists of the 1-, 2-, 3-, 4-, 5-, 6-, 7-, and 8-foot size; and a third group consists of the large size including the 10-, 12-, 15-, 20-, 25-, 30-, 40-, and 50-foot sizes.

The general ratio of dimensions of the "inch-size" group, the intermediate group, that 1-foot to 8-foot, and the large-size group, vary. Therefore, it is necessary to refer to the tables of dimensions for each particular size in the design and construction of any selected flume. Figures 6, 7, and 8 and tables 12, 13, and 14 provide these dimensions.

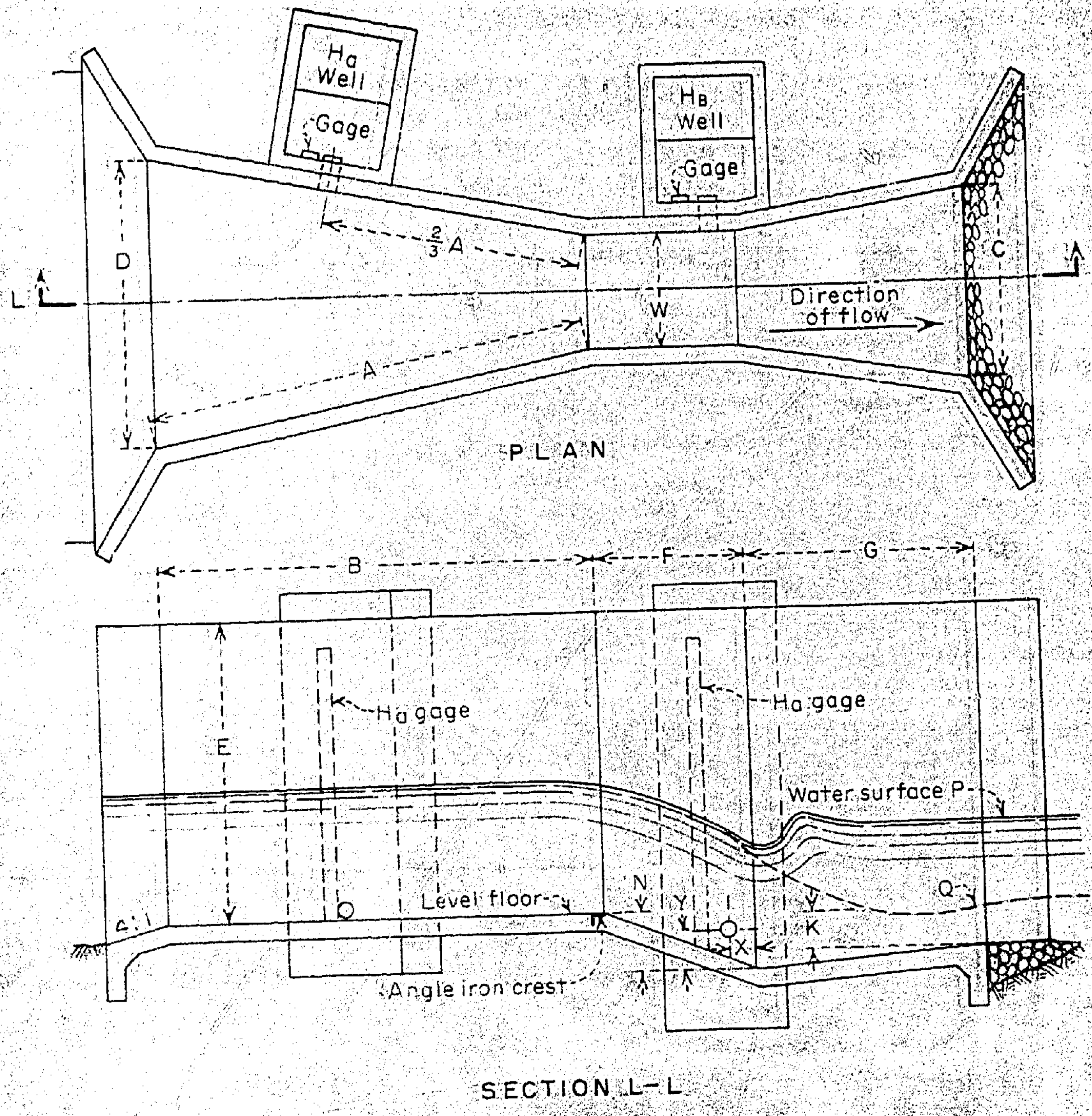

Figure 6. Plan and elevation of the Parshall flume, 3, 6 and 9-inch sizes.

TABLE 12 - DIMENSIONS AND CAPACITIES OF THE PARSHALL MEASURING FLUME, FOR THE 3-, 6-, AND 9-INCH CREST LENGTHS

Letters refer to figure 6

W	A		2/3 A		B		C		D		E		F
Inches	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
3	1	6-3/8	1	½	1	6		7		10-3/16	1	3	½
6	2	7/16	1	4-5/16	2		1	3½	1	3½	1	6	1
9	2	10-5/8	1	11-1/8	2	10	1	3	1	10-5/8	2		1

W	G	K	M	X	Y	Free-flow Maximum	Capacity Maximum
Inches	Ft.	In.	In.	In.	In.	Sec.-ft.	Sec. - Ft.
3	1	1	2¼	1	1½	1.2	0.03
6	2	3	4½	2	3	2.9	.05
9	1½	3	4½	n2	3	5.7	.1

TABLE 13- STANDARD DIMENSIONS AND CAPACITIES OF THE PARSHALL MEASURING FLUME

Letters refer to figure 7

Crest Length W	A	2/3 A	B	2/3 B	C	D	Free-flow Maximum Head Ha	Capacity Disch.	Minimum Head Ha	Disch.
Feet							Ft.	Sec.-ft.	Ft.	Sec.-Ft.
1	4'6"	3'0"	4' 4-7/8"	2' 11¼"	2	2' 9¼"	2.50	16.1	0.20	0.35
2	5'10"	3'4"	4' 10-7/8"	3' 3½"	3	3' 11-½"	2.50	33.1	0.20	0.66
3	5'6"	3'8"	5' 4-3/4"	3' 7-1/8"	4	5' 1-7/8"	2.50	50.4	0.20	0.97
4	6'0"	4'0"	5' 10-5/8"	3' 11-1/8"	5	6' 4¼"	2.50	67.9	0.20	1.26
5	6'6"	4'4"	5' 4½"	4' 3"	6	7' 6-5/8"	2.50	85.6	0.25	2.22
6	7'0"	4'8"	6' 10-3/8"	4' 6-7/8"	7	8' 3"	2.50	103.5	0.25	2.63
7	7'6"	5'0"	7' 4½"	4' 10-7/8"	8	9' 11-3/8"	2.50	121.4	0.30	4.08
8	8'0"	5'4"	7' 10-1/8"	5' 2-3/4"	9	11' 1-3/4"	2.50	139.5	0.30	4.62

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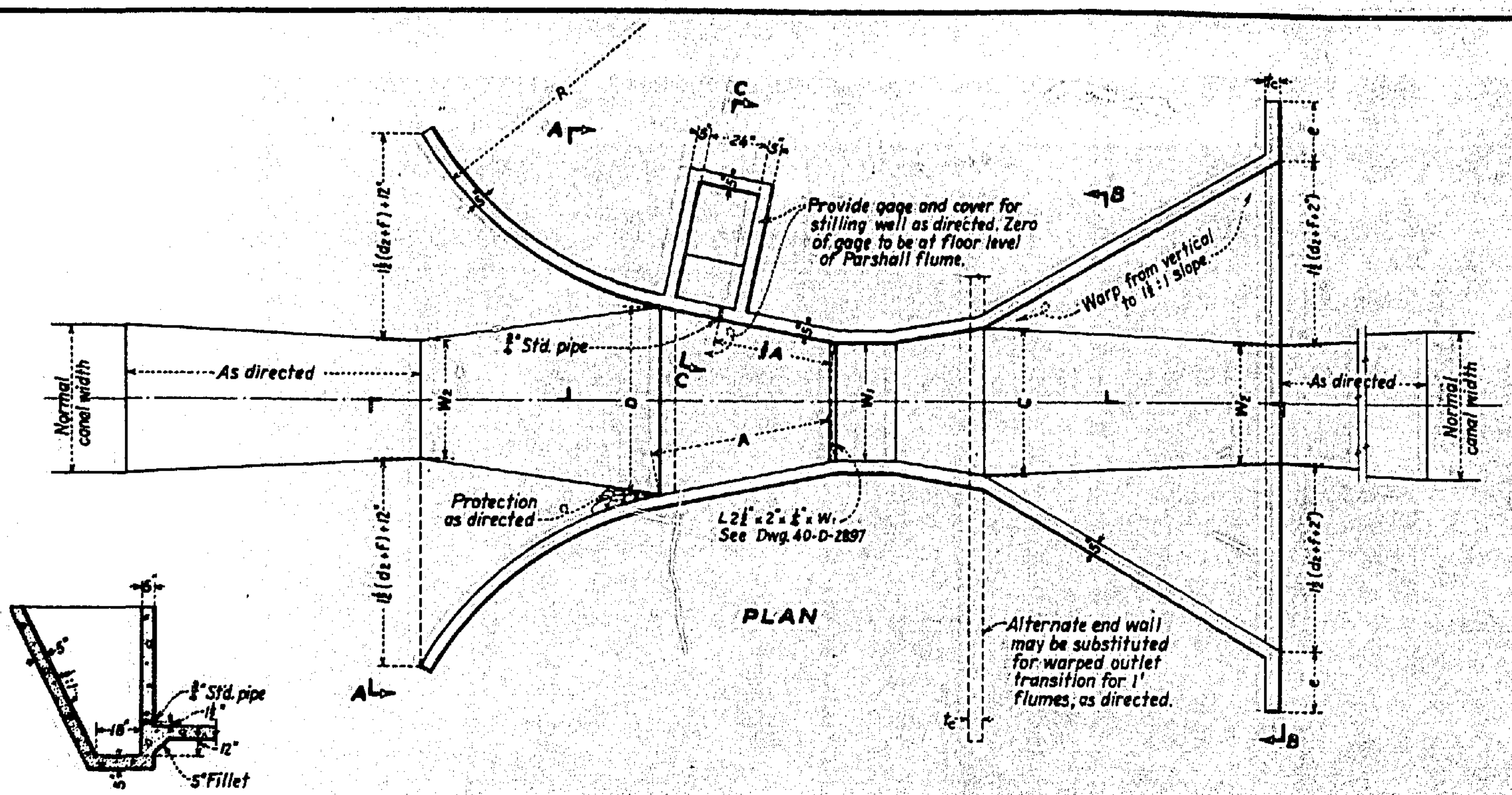

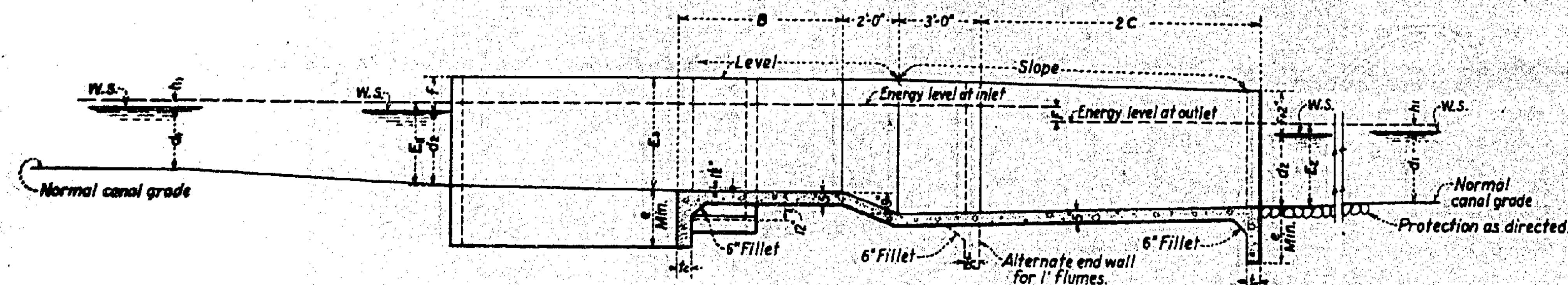

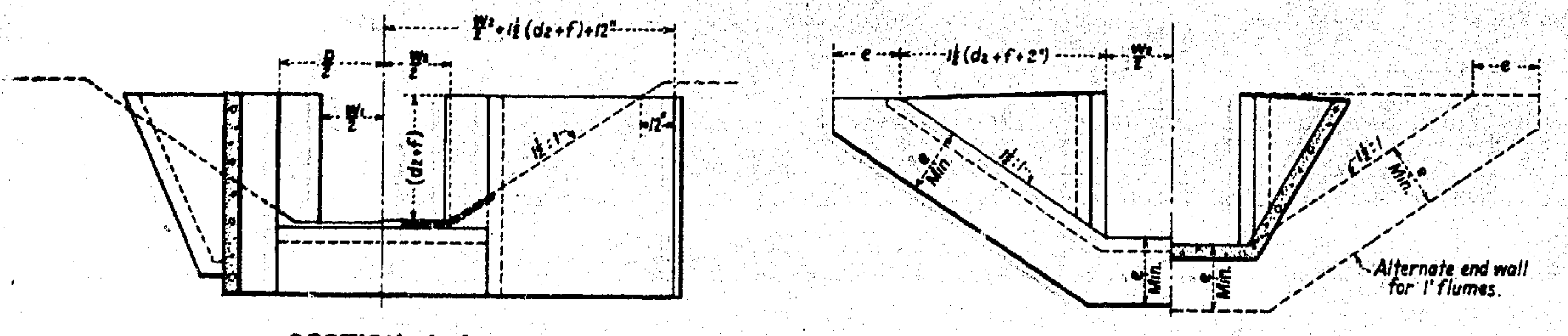

HYDRAULIC TABLE

FOR FREE FLOW DISCHARGE

	1' FLUME				2' FLUME				3' FLUME				4' FLUME			
d_2	Q	E_2	E_3	Min F	Q	E_2	E_3	Min F	Q	E_2	E_3	Min F	Q	E_2	E_3	Min F
.2	.29	.21	.21	.08												
.3	.50	.31	.31	.09												
.4	.88	.41	.42	.13	1.3	.41	.35	.13								
.5	1.52	.52	.56	.18	2.1	.52	.46	.15								
.6	2.18	.62	.71	.22	2.9	.62	.57	.18								
.7	3.00	.73	.87	.25	3.9	.73	.69	.22								
.8	3.84	.84	1.05	.29	5.0	.84	.81	.25								
.9	4.80	.94	1.22	.34	6.3	.94	.93	.29	6.0	.92	.71	.22				
1.0	6.02	1.05	1.38	.39	7.6	1.05	1.07	.32	7.3	1.03	.80	.24				
1.1					9.5	1.15	1.22	.35	8.7	1.13	.90	.26				
1.2					11.2	1.26	1.36	.38	10.4	1.24	1.00	.28				
1.3					13.0	1.37	1.52	.41	12.0	1.34	1.10	.31	12.0	1.33	.95	.31
1.4					15.2	1.47	1.67	.45	13.9	1.44	1.22	.33	13.9	1.44	1.04	.34
1.5					17.6	1.58	1.82	.50	15.8	1.54	1.34	.36	15.8	1.54	1.13	.36
1.6					20.0	1.68	1.97	.54	18.0	1.65	1.46	.39	18.0	1.65	1.22	.38
1.7									20.3	1.75	1.58	.42	20.3	1.75	1.32	.41
1.8									22.9	1.86	1.70	.45	22.9	1.86	1.43	.44
1.9									25.5	1.96	1.82	.48	25.5	1.96	1.54	.46
2.0									28.3	2.06	1.95	.52	28.3	2.06	1.64	.48
2.1									31.3	2.16	2.08	.55	31.3	2.16	1.74	.50
2.2									34.4	2.27	2.21	.58	34.4	2.27	1.85	.52
2.3									37.7	2.37	2.35	.62	37.7	2.37	1.97	.54
2.4									41.0	2.48	2.48	.66	41.0	2.48	2.08	.57
2.5									44.8	2.58	2.61	.69	44.8	2.58	2.20	.60
2.6									48.5	2.69	2.75	.73	48.5	2.68	2.32	.63
2.7													52.5	2.79	2.44	.66
2.8													56.5	2.89	2.56	.69
2.9													60.7	3.00	2.67	.72
3.0													65.0	3.10	2.79	.75

EXPLANATION

A, B, C, D, W_1 = dimensions for Parshall flume
d_1 = depth of water in normal canal section.
d_2 = depth of water in canal section having base width W_2, side slopes 1½:1.
e = cut-off dimension.
E_2, E_3 = assumed energy heights to be used in setting elevations.
f = freeboard above water surface for d_2 at inlet.
F = drop in energy line thru flume.
h_1 = velocity head in normal canal section.
Q = cubic feet per second, normal discharge.
R = radius of inlet walls = 3 (d_2 + f).
W_1 = Throat width and size designation for Parshall flumes.
W_2 = base width of canal section at ends of Parshall flume

For a given Q select the smallest size of flume adaptable to the canal section from Hydraulic Table, (by interpolation if necessary) obtain d_2, E_2, E_3, and minimum F. For maximum F see Structural Table below.
For discharge of Parshall flumes, see Bulletin 336, Colorado Experiment Station, Colorado Agricultural College, Fort Collins, Colorado.

NOTES

Reinforcement steel not shown. Reinforcement [illegible] both ways in center of slabs. Extend longit. bars from floor and walls into cut-offs. Transverse bars continuous in walls and floor. Bond horizontal bars from stilling well 13" into vertical walls of flume.
Lap all bars 34 diameters at splices.

STRUCTURAL TABLE

W_1	A	B	C	D	Min F	e	tc	W_2	F
1'	4'-6"	4'-4⅞"	2'-0"	2'-9¼"	.39	18"	5"	2'	6"
2'	5'-0"	4'-10⅞"	3'-0"	3'-11½"	.34	18"	5"	3'	8"
3'	5'-6"	5'-4¾"	4'-0"	5'-1⅞"	.73	24"	6"	4'	10"
4'	6'-0"	5'-10⅝"	5'-0"	6'-4¼"	.75	24"	6"	4'	12"

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ALTUS PROJECT – OKLAHOMA

CONCRETE PARSHALL FLUMES
MAXIMUM CAPACITY 65 SECOND FEET

DRAWN [illegible] SUBMITTED [illegible]
TRACED [illegible] RECOMMENDED [illegible]
CHECKED [illegible] APPROVED [illegible]

Figure 7

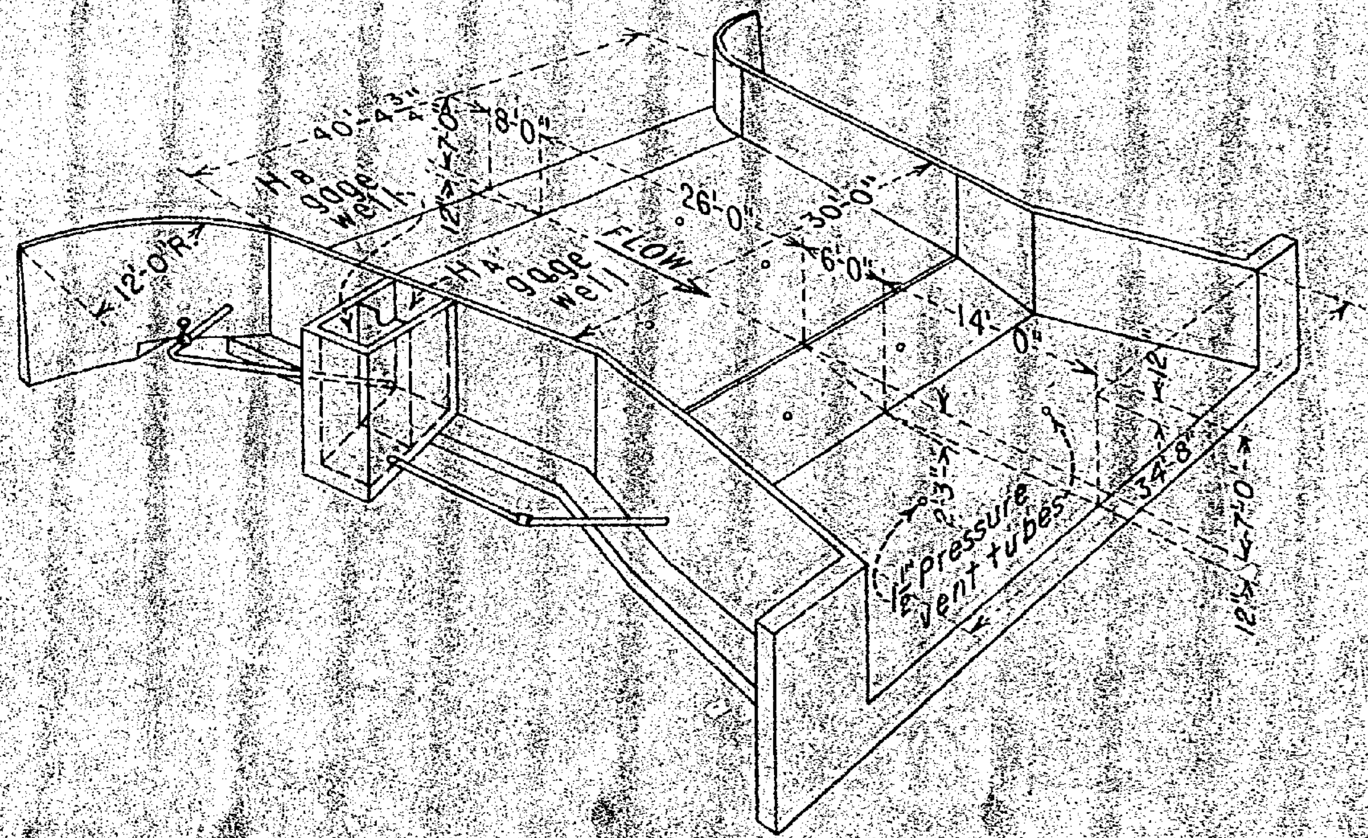

Figure 6. - Large Parshall flume with 30-foot throat. Dimensions for other large flumes are shown in table 14.

TABLE 14 - DIMENSIONS AND CAPACITIES FOR PARSHALL MEASURING FLUMES OF LARGE SIZE

Size-throat width	Free-flow capacity		Axial length		
	Maximum	Minimum	Converging	Throat	Diverging
Feet	Sec.-ft.	Sec.--ft.	Feet	Feet	Feet
10	200	6	14	3	6
12	350	8	16	3	8
15	600	8	25	4	10
20	1000	10	25	6	12
25	1200	15	25	6	13
30	1500	15	26	6	14
40	2000	20	27	6	16
50	3000	25	27	6	20

Size-throat width	Width		Wall depth converging section	Vertical distance below crest		H_a gage distance (not axial)*
	Upstream end	Down-stream end		Dip at throat	Lower end flume	
Feet	Feet	Feet	Feet	Feet	Inches	Feet
10	15'7.25"	12' 0"	4	1'1.5"	6	6'0"
12	18'4.75"	14' 8"	5	1'1.5"	6	6'8"
15	25' 0"	18' 4"	6	1'6"	9	7'8"
20	30' 0"	24' 0"	7	2'3"	12	9'4"
25	35' 0"	29' 4"	7	2'3"	12	11'0"
30	40'4.75"	34' 8"	7	2'3"	12	12'8"
40	50'9.5"	45' 4"	7	2'3"	12	16'0"
50	60'9.5"	56' 8"	7	2'3"	12	19'4"

Note: For all these sizes the H_a gage is located 12 inches upstream from, and 9 inches above the floor at, the downstream edge of throat.

*H_a gage distance is measured along flume wall, upstream from the crest line.

Free flow through a Parshall flume occurs when the elevation of the surface of the flow downstream from the throat is not high enough to cause any retardation of the flow due to backwater. In general, free flow exists when the upstream floor of the flume is placed at such an elevation above the channel bottom that the difference in elevation between the water surface at the upstream gage and the water surface near the lower end of the throat section is greater than 40 percent of the depth of flow at the upstream gage, in the case of the "inch-size" flumes, and in the case of the one-foot and larger flumes, 30 percent.

27. Characteristics of the flume. After considerable and wide-spread usage of the Parshall flume by irrigation interests in the west it is apparent that this device has many desirable characteristics and is not subject to many of the disadvantages of other devices.

It may be operated as a free-flow, single-head device, or under submerged flow conditions where two heads are used.

Because of the contracted section at the throat, the velocity of water flowing through the structure is relatively greater than the natural flow of the stream, and for this reason any sand or silt in suspension or rolled along the bottom of the channel is carried through, leaving the flume free of deposit.

Velocity of approach, which often becomes a serious factor in the operation of weirs has little or no effect upon the rate of discharge of the flume.

It is accurate enough for all irrigation purposes, and since it remains clean of sediment the reliability of its measurements is believed to be greater than that of other methods all other factors remaining equal. The loss of head for the free-flow limit is much smaller than for weirs making its installation and use possible on relatively flat grades. A wide range of capacity of measurement has been provided in its calibration. It is, therefore, adaptable for use on the farm lateral as well as on channels of large capacity.

The Parshall flume has certain disadvantages like all measuring devices. One is that the flume cannot be used or combined with a turnout or headgate. The flume is more expensive to build than other commonly used devices such as the weir or submerged orifice. It also requires more accurate workmanship in its construction.

25. Free-flow discharge. The free-flow discharge through the Parshall measuring flume is defined as that condition of flow where the degree of submergence does not retard or resist the rate of discharge.

The fundamental formula for free-flow discharge through the Parshall flume is:

$$Q = J H_a^n \qquad (15)$$

where Q = discharge in second-feet

J = coefficient which is a function of the size of the flume

H_a = the upper head, in feet, observed at a point distant upstream from the crest two-thirds the length of the converging section, and

n = exponent of the head, H_a

(a) 3-, 6-, and 9-inch flumes:

Calibration of these small flumes lead to the development of the following formulas for their free-flow discharge:

3-inch flume $Q = 0.992 H_a^{1.547}$ (16)

6-inch flume $Q = 2.06 H_a^{1.58}$ (17)

9-inch flume $Q = 3.07 H_a^{1.53}$ (18)

Free-flow discharge for 3-, 6-, and 9-inch flumes is given in tables 15, 16, and 17. (See section 84)

(b) Parshall flumes, 1-foot to 8-feet in size. The calibration tests on this group of flumes lead to the development of the following formula for discharge of the flumes falling within this group:

$$Q = 4W H_a^{1.522 W^{0.026}} \qquad (19)$$

where Q = discharge in second-feet, and

W = size of flume, or width of the throat, in feet.

This formula is in the form of formula (15), J being equal to 4W and n being equal to $1.522\ W^{0.026}$.

For convenience, in table 18 (See section 84) are given the free-flow discharges of 1-, 2-, 3-, 4-, 5-, 6-, 7-, and 8-foot Parshall flumes for free-flow.

(c) Parshall flumes of large size. The free-flow discharge formula for small flumes (1- to 8-foot size), $Q = 4W\ H_a^{1.522\ W^{0.026}}$, when extended to large structures is found to give a discharge in excess of the actual flow. In developing the general discharge formula for the large flumes, a more simplified expression has been found to be applicable to flumes ranging in size from 8 to 40 feet. This general discharge formula is:

$$Q = (3.6875\ W + 2.5)\ H_a^{1.6} \qquad (20)$$

where Q, W and H_a have the same significance as described in previous equations. The free-flow discharge computed by this formula for an 8-foot flume differs by less than 1 percent from the general formula applicable to the smaller flumes.

Tables 19 to 26, inclusive, (see section 84) give the discharge in second-feet for throat widths of 10, 12, 15, 20, 25, 30, 40, and 50 feet, respectively. In these tables it is possible, by estimation, to read the free-flow discharge in second-feet with an error of less and 1 percent.

29. Submerged Flow.

(a) 3-, 6-, and 9-inch flumes:

No submerged flow formulas for the 3- and 9-inch flumes have been developed.

The discharge for submerged flow for the 6-inch flume may be computed from the following formula:

$$Q = 2.06\ H_a^{1.58} - \left[\frac{0.072\ H_a^{2.22}}{\left(\frac{H_a + 10}{10} - K\right)^{1.44}} - \frac{H_a - 0.184}{8.17}\right] \qquad (21)$$

where Q = discharge in second-feet

H_a = upper head in feet

60

K = the ratio, throat head to upper head, or H_b/H_a expressed as a decimal.

The use of this formula is cumbersome and for this reason figure 10 has been prepared to assist in the computation of discharges through the 6-inch flume.

Figures 9 and 11 provide diagrams for computing submerged flow through 3-inch and 9-inch Parshall flumes, respectively. The use of figures 9, 10 and 11 is similar to that of figure 12 which is explained is section 29 b which follows.

(b) 1- to 8-foot Parshall flumes: The following is the complete formula for computing the discharge through the Parshall flume for submerged flow:

$$Q = 4W\, H_a^{1.522\, W^{0.026}} - \left[\left(\frac{H_a}{\left(\frac{1.8}{K}\right)^{1.8} - 2.45} \right)^{4.57-3.14K} + 0.093K \right] W^{0.815} \qquad (22)$$

where Q = discharge in second-feet

W = size of flume or width of flume, in feet

H_a = the upper head in feet observed at a point distant upstream from the crest two-thirds the length of the converging section

K = the degree of submergence expressed as a decimal fraction.

To facilitate the use of this submerged-flow correction formula, the values [illegible] C [illegible] a 1-foot flume may be taken directly from the diagram, figure 12. To determine the submerged-flow correction for other sizes of flume, multiply this correction by the factor M, as given in the following tabulation before subtracting from the corresponding free flow for that particular H_a head.

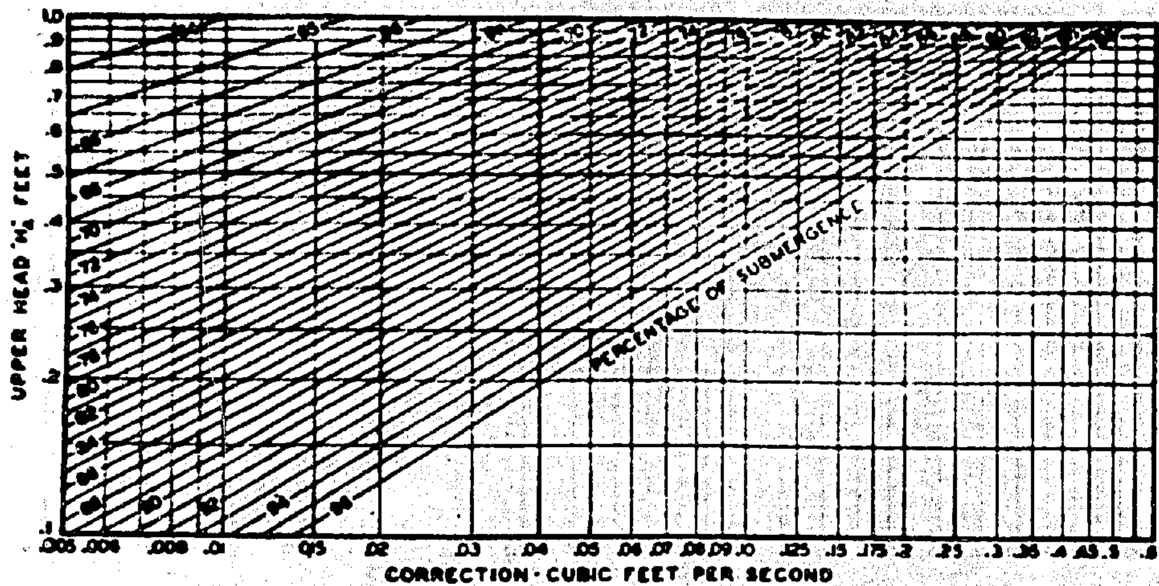

Figure 9. Diagram for computing submerged flow through 3-inch Parshall flume.

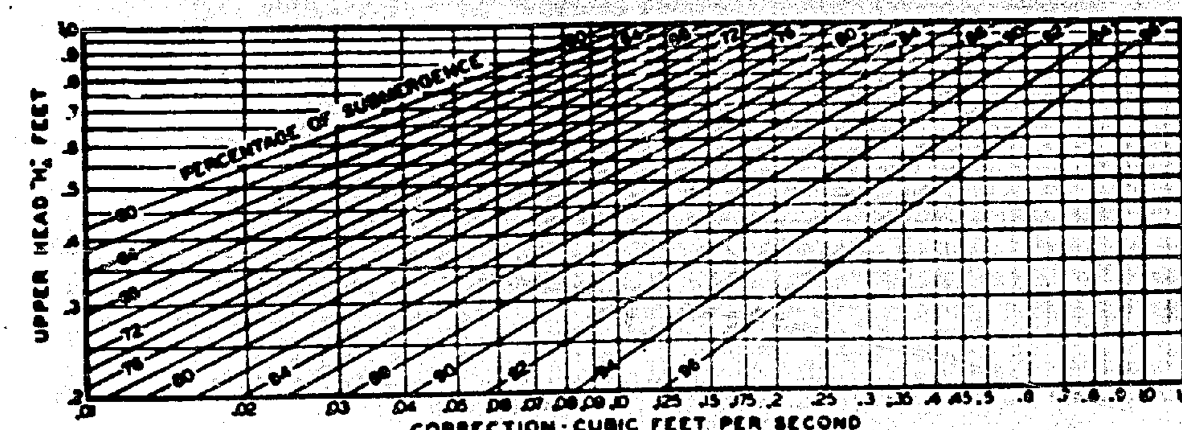

Figure 10. Diagram for computing submerged flow through 6-inch Parshall flume.

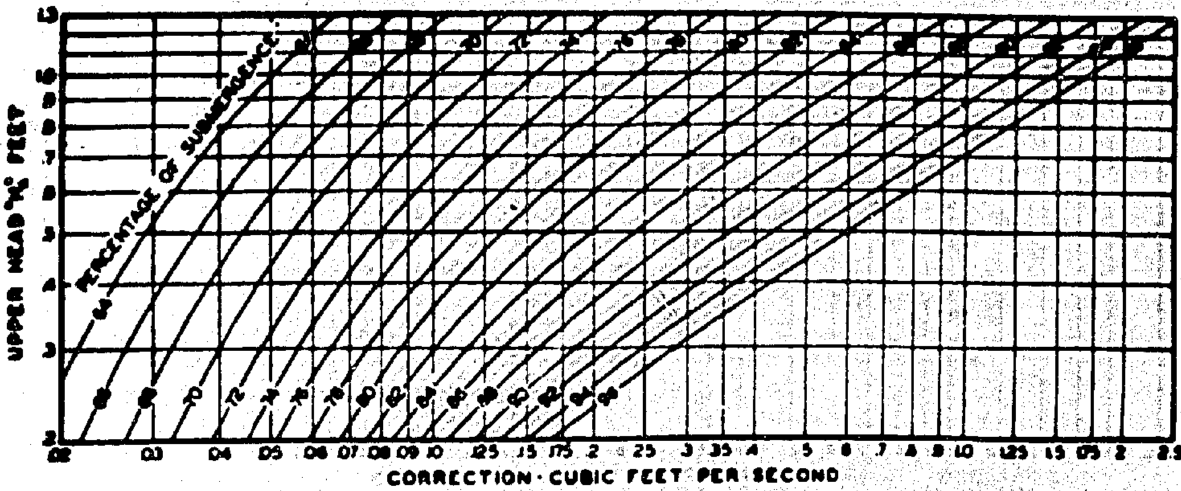

Figure 11. Diagram for computing submerged flow through 9-inch Parshall flume.

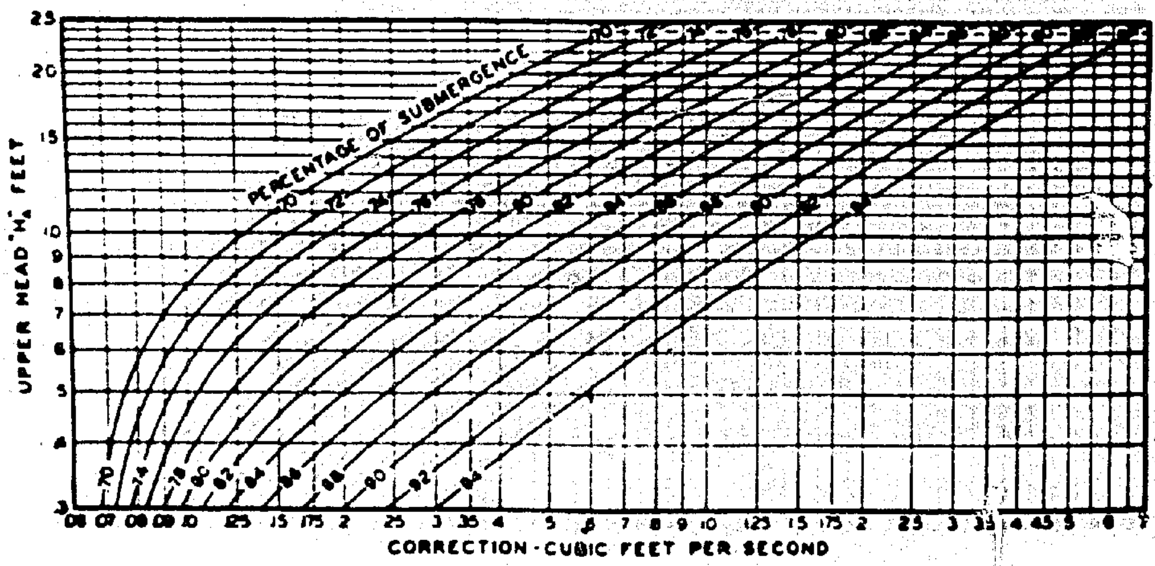

Figure 12. Diagram for computing submerged flow through 1-foot Parshall flume.

Size of flume	Multiplying factor (M)	Size of flume	Multiplying factor (M)
Width in feet		Width in feet	
1	1.0	5	3.7
2	1.8	6	4.3
3	2.4	7	4.9
4	3.1	8	5.4

The following example is given to illustrate the method of computing the discharge of Parshall flumes under submerged conditions:

(1) Let it be assumed that the flume has a throat width of one foot; upper head, H_a, 1.50 feet; and the throat head H_b, 1.20 feet. The ratio 1.20/1.50 = 0.80. Enter diagram, figure 12 at the left hand side on the H_a line 1.5, follow this horizontal line to the right until reaching the curved line 80. Vertically beneath this intersection observe the reading 0.71, which is the correction in second-feet due to the submergence. In the free-flow discharge, table 18, for the 1-foot flume with the recorded head, H_a, of 1.50 feet, not that the discharge is 7.41 second-feet. The flow with a submergence of 80 percent under these conditions will, therefore, be 7.41 - 0.71 = 6.70 second-feet.

(2) What will be the discharge through a 4-foot flume where the upper head Ha is 1.98 feet and the throat head, H_b, is 1.80 feet? The ratio 1.80/1.98 is very closely 0.91. As before, enter the correction diagram at the left; however, in this case follow to the right along the horizontal line indicating H_a = 2.0 until the point is reached midway between curved line 90 and 92. It is to be kept in mind that the line H_a = 2.0 is slightly above the true value of the upper head, which is 1.98 feet. At this corrected point, move vertically downward to the base of the diagram and estimate the value on this scale at 3.50 second-feet, which is the submergence correction for a 1-foot flume. It will be noted in the previous tabulation that the multiplying factor, M, for the 4-foot flume is 3.1. This factor times the correction in second-feet is 10.85 second-feet or the amount to be deducted from the free flow through the 4-foot flume for an upper head H_a of 1.98 feet.

The computed submerged flow is, therefore, 36.17 second-feet.

(3) Suppose the upper head, H_a, of an 8-foot flume is 0.69 foot and the throat head, H_b, is 0.60 foot, what would be the submerged-flow discharge? The ratio of the two heads will be 0.60/0.69 or very closely 0.87. As before, enter the correction diagram at the left and follow horizontally to the right on the line 0.7 to a point about midway between the curved lines "86" and "88". Since the value of the H_a head is 0.69 foot, it will be necessary to select the true point about one tenth the interval below the 0.7 H_a line. Vertically below this final location of the true point there will be found, on the base of the diagram, the value of 0.41 second-foot as the correction for submergence for the 1-foot flume. The multiplying factor, M, for the 8-foot flume is 5.4, which multiplied by 0.41 second-feet equals 2.21 second-feet, the correction. The free-flow discharge through the 8-foot flume for an upper head, H_a, at 0.69 foot is 17.63 second-feet. The computed submerged flow will be 17.63 - 2.21 = 15.42 second-feet. For this degree of submergence it is readily determined that the free-flow discharge has been reduced approximately 12.5 percent.

(c) Parshall flumes of large size. To determine the rate of submerged flow in large flumes use is made of figure 13, a correction diagram showing the amount in second-feet to be deducted for each 10 feet of crest from the free-flow discharge for that particular value of H_a. At the left, vertically, are given the values of the upper head, H_a, in feet. Crossing the diagram diagonally are straight lines indicating the ratio H_b/H_a, the degree of submergence, and along the base of the diagram is the correction in second-feet. The following tabulation gives the multiplying factor for correcting the indicated value from the diagram for the various sizes of flumes:

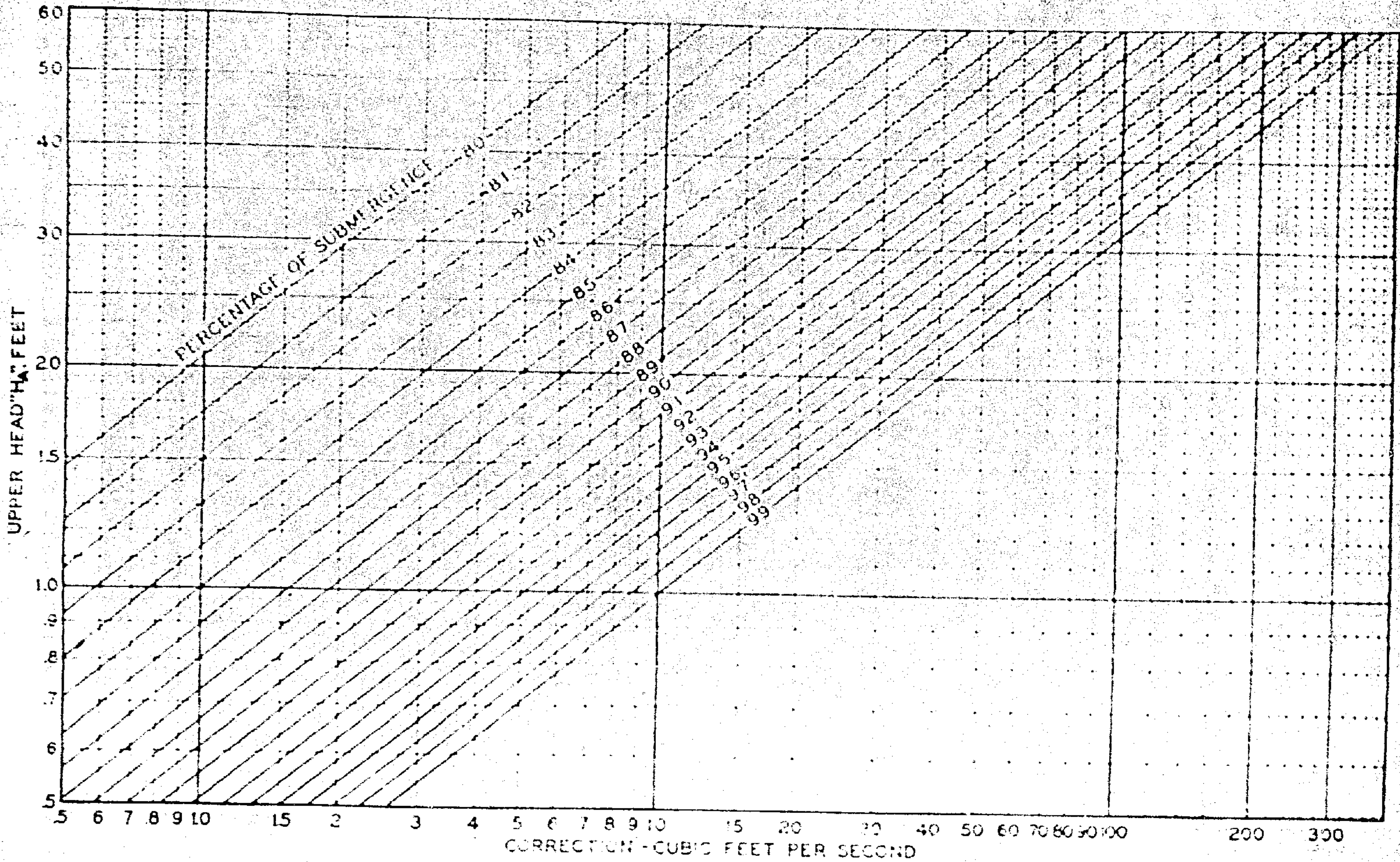

Figure 13. Diagram for determining the correction in second-feet per 10 feet of crest for submerged-flow discharge.

Size of flume	Multiplying factor	Size of flume	Multiplying factor
Width in feet		Width in feet	
10	1.0	25	2.5
12	1.2	30	3.0
15	1.5	40	4.0
20	2.0	50	5.0

An illustration of the use of the correction diagram follows: Let it be assumed that the upper head, H_a, on a 20-foot Parshall flume is 3.25 feet and H_b, the lower head, is 3.06 feet, and the discharge is required. The ratio H_b/H_a = 3.06/3.25 or 0.941. On the diagram, figure 13, find the value of H_a at 3.25 feet at the intersection with the diagonal line 94; then by estimation advance one-tenth of the distance between the lines 94 and 95. Vertically below this point, a correction of 56 second-feet is indicated. From table 22 the free-flow discharge through a 20-foot flume with an upper head, H_a, of 3.25 feet is found to be approximately 503 second-feet. The submerged flow, then, is 503-(2 x 56) or 391 second-feet. The correction is determined in the same manner for submerged flow through other sizes of flumes. For a 10-foot flume, the correction is as shown by the diagram; for the 12-foot flume the correction as indicated by the diagram is to be multiplied by 1.2 before subtracting from the free-flow rate of discharge.

30. Selection of size, setting, and construction of the Parshall flume. This device, like any other water-measuring structure must be properly installed and maintained to give the most satisfactory results. Proper size of the flume is of prime importance. Within certain limits of head, a particular discharge may be measured by any one of various sizes of flumes. Probably only one size will be the most economical from the standpoint of cost, the limit of loss of head being specified. In many cases the loss of head is the limiting factor to be considered in the selection of a flume.

The Bureau has prepared the general design of the Parshall flume shown in figure 7 to provide a method for setting the flume at the correct elevation, with the minimum drop required, using only the "H_a" reading. Discharges and energy heights were computed for ditches with bottom widths of 2, 3, and 4 feet, on grade slopes suitable for earth sections. The energy heights in the stilling well were computed for these discharges for 1-, 2-, 3-, and 4- foot Parshall flumes, where they would apply.

The hydraulic properties of the ditch in which the Parshall flume is to be installed may differ from the above assumed sections, but if one of these sections has about the same energy height for the given discharge, Q, it can be substituted at the ends of the flume, thus giving a definite set of conditions for the elevations and dimensions of the flume.

For example, suppose a Parshall flume is to be installed in a ditch with a 3-foot bottom width, 1½ to 1 side slopes, depth of water of 1.6 feet and a velocity of 2.6 feet per second. This accounts for 22.46 second-feet flow. The energy height is $1.6 + \frac{2.6^2}{2g} = 1.6 + 0.11 =$ 1.71 feet. In the Hydraulic Table found on figure 7, it is seen that for a discharge, Q, of 22.46 second-feet the E_2 and E_3 values nearest the value of 1.71 are in the column under the 3-foot flume, and that d_2 lies between 1.7 and 1.8. Interpolation gives a value of d_2 as 1.78 for a discharge, Q, of 22.46 second-feet. By interpolation, for a d_2 of 1.78 feet, E_2 is found to be 1.84 feet, E_3 is 1.68 feet and the drop of energy through the flume is 0.44 feet (designated as "Min. F" in the table). If the 4-foot flume had been selected E_3 would have had a value of 1.41 feet requiring the flume to be set 0.3 feet above the ditch grade.

Where a difference of 0.05 feet in the water surface would not interfere with the successful operation of the ditch, interpolation is not necessary and values can be selected for the nearest d_2 value for the given discharge, Q, and flume size.

Having obtained the values d_2, E_2, E_3, and energy drop through flume (Min. F) the dimensions for the flume selected are taken from the structural table on figure 7. The essential proportions and dimensions of the flumes are also found in table 13.

68

Hydraulic tables for the 4-foot to 8-foot flumes are in the process of preparation.

Small Parshall flumes may be constructed of wood, concrete, or steel. Small flumes available commercially are fabricated of sheet steel reinforced with structural shapes, all treated against rust and corrosion. However, a large proportion of new Parshall flume installations large and small now being installed are of concrete.

Where a number of small flumes of the same size are to be built it will be found economical and practicable to build portable knock-down forms for re-use on many installations.

The highest quality of design, workmanship, and construction practice should be employed in the construction of the footings and setting the forms for, and pouring the monolithic concrete structure, as the accuracy of the flume depends on correct dimensions and setting.

The essential features in the building of Parshall flumes are correct finished dimensions and correct alignment. The floor of the converging section should be level. This is highly important and the accuracy of the flume depends to a large degree on this item. The downward-sloping floor in the throat should be a plane surface, pitched to the proper dimensions as indicated on the type-plans and tables shown herein. The crest formed by the juncture of the converging section and the downward-sloping section must be level and straight.

To provide a sharp and definite edge to serve as the crest a common and effective method is to fix and level a substantial angle iron in the proper position.

The inside faces of the walls should be straight, smooth, and vertical. The floors of large flumes should be provided with pressure vent tubes as indicated in figure 8. The apron at the upstream end of the flume as well as the wing walls reaching back to the banks of the channel which serve to lead the stream of water into the entrance of the flume with slight loss of head, should all be smooth and regular to insure good flow conditions.

Another feature on which the accuracy of the flume depends is the proper and accurate location and installation of the upper and lower gage points.

The correct dimensions are shown in figures 6 and 7 and tables 12, 13, and 14 for the three different types of Parshall flumes. The inlet openings into the flume for both Ha and H_b gages must be set flush with the inside face of the wall, and must be permanently fixed in position and neatly finished.

31. Stilling Wells. In small flumes, discharging under free-flow conditions, H_a head is generally determined by a simple staff gage placed vertically at the correct position on the face of the wall of the converging section of the flume. An enameled metal gage graduated in feet, tenths, and hundredths may be used. To provide for smooth flow of water passing the gage, it should be recessed flush with the surface of the wall.

In small flumes which are likely to flow under submerged conditions, for dependable measurements of H_a and H_b head, stilling wells should be provided along the outside of the flume structure. The stilling wells may be cast integral with the flume structure, in the case of concrete construction, or the wells may be built separately of any suitable material and connected by suitable pipe to the correct gage points.

Vitrified clay tile, plugged at the spigot end and punctured at proper height for a pipe leading from the flume, are commonly used. Bulletin 488, Colorado Experiment Station, Fort Collins, Colorado, treats in detail the subject of stilling wells made from vitrified tile for small flumes.

In measuring the flow through large Parshall flumes effective heads H_a and H_b must be carefully determined. Readings on a staff gage attached to the inside face of the flume wall will give only approximately head H_a and it is quite impossible to obtain accurate H_b readings by means of a staff gage located in that section of the flume. In order to obtain reliable and accurate gage readings, a double stilling well should be provided at a point where the gage inlet tubes will pass diectly into the H_a compartment, while the head for the H_b gage may be brought back the other compartment through a suitable pipe leading from the proper point in the throat section, as shown in figure 8.

CHAPTER IV - SUBMERGED ORIFICES

32. Use of submerged orifices. Where there is sufficient fall to permit the measurement of water by means of a weir of reasonable length, (or head, in the case of a V-notch weir), the weir should normally be chosen as the most desirable measuring device, as it will be more nearly free from detrimental effects of weeds and trash and the cost will normally be less than for other structures. Where, however, the amount of fall available for measuring the water is not adequate for the use of a weir, the Parshall flume or the submerged orifice may be used. For situations where a more permanent installation is not desirable or feasible, the orifice should be used. For permanent installations the Parshall flume is the more desirable.

In the measurement of water in laterals and farm ditches a weir can generally be used for all cases where there is as much as 0.5 of a foot of fall available, and even under the most adverse conditions the weir can be used for all falls exceeding 1 foot.

The more serious disadvantages of the submerged orifice are the collecting of floating debris and the collecting of sand and silt above the orifice and thus preventing accurate measurement.

33. Definition and classification of orifices. An orifice may be defined as an opening so placed in a wall of a channel or vessel carrying or holding water that the opening lies completely below the surface of the water on the upstream side thereof. The wall may have any anguler position from horizontal to vertical, the opening may have any geolmetrical shape, the water may discharge into air or into water, and the issuing stream may or not be contracted.

The orifices generally employed for the measurement of irrigation water are either circular or rectangular and are vertical; that is, are placed in a vertical wall in a carrying channel. In the early days of irrigation such an orifice usually discharged into air, in which case

72

the orifice was said to be free. Since the more general adoption of the weir for measuring irrigation water the free orifice has been practically abandoned because it requires considerable fall for its use and, when the fall is available, the weir is more applicable.

Later practice developed the use of an orifice that discharges into water; such an orifice is said to be submerged. The submerged orifice is used where there is insufficient fall for the use of a weir, and the Parshall flume is considered not feasible because of permanency and special field conditions and cost.

In addition to the subdivision of vertical orifices into free and submerged orifices, either of these classes may be contracted or suppressed. A contracted orifice is one with its perimeter so far removed from the bounding surfaces of the water prism in the channel of approach or other surfaces of a distrubing nature that the filaments of water are fully contracted or deflected as they pass through the orifice. A suppressed orifice is one with its perimeter coincident with the sides of the channel of approach or with other surfaces eliminating contraction.

Evidently an orifice may be contracted or suppressed on any part or all its perimeter or it may be imperfectly contracted and suppressed on any part or all of its perimeter. The latter condition may occur if the opening is not sharp-edged or if the wall in which it is cut or formed has considerable thickness or if a discharge tube is attached, in which case the opening becomes a submerged tube. This condition may exist all around the opening or only partially so, or it may be caused by placing too close to the opening the bounding surfaces of the water prism in the channel of approach. For these different conditions different coefficients of discharge apply.

34. Type of orifice adopted. The principal type of orifice adopted by the Bureau of Reclamation for the measurement of irrigation water is the vertical, sharp-edge, contracted, rectangular, submerged orifice. The reasons for selecting this type for general use are that it is well suited for securing accuracy and is the principal type for

which the discharge coefficient has been carefully determined. Such an orifice is illustrated in figure 14.

35. Definition and conditions for accuracy of standard submerged rectangular orifices. The standard submerged rectangular orifice is a submerged rectangular orifice with its four sides consisting of thin-edged plates, each so far removed from the adjacent sides, bottom, or top of the water prism in the leading channel as to cause the filaments of water to be fully deflected from their normal course as they pass through the orifice. The deflection is approximately the maximum deflection that would be obtained with the sides of the orifice at unlimited distances from the water prism boundaries.

The sides of the orifice may be of planks if the upstream edges are definite, rectangular corners, but it is best to use a thin metal plate.

The following conditions are considered necessary to secure adequate contraction and satisfactory accuracy of measurement:

(a) The upstream edges of the orifice should be sharp and smooth and the distance of each from the bounding surfaces of the channel, both on the upstream and on the downstream side, should preferably be not less than twice the least dimension of the orifice.

(b) The upstream face of the orifice wall should be vertical.

(c) The top and bottom edges should be level from end to end.

(d) The sides should be truly vertical.

(e) The head on the orifice that should be measured is the actual difference in elevation between the water surface on the upstream side of the orifice and the water surface on the downstream side thereof.

(f) The cross-sectional area of the water prism for 20 to 30 feet from the orifice on the upstream and the downstream sides thereof should be at least six times the cross-sectional area of the orifice.

(g) Correction should be made for velocity of approach where appreciable errors are caused by neglecting the head due to it.

74

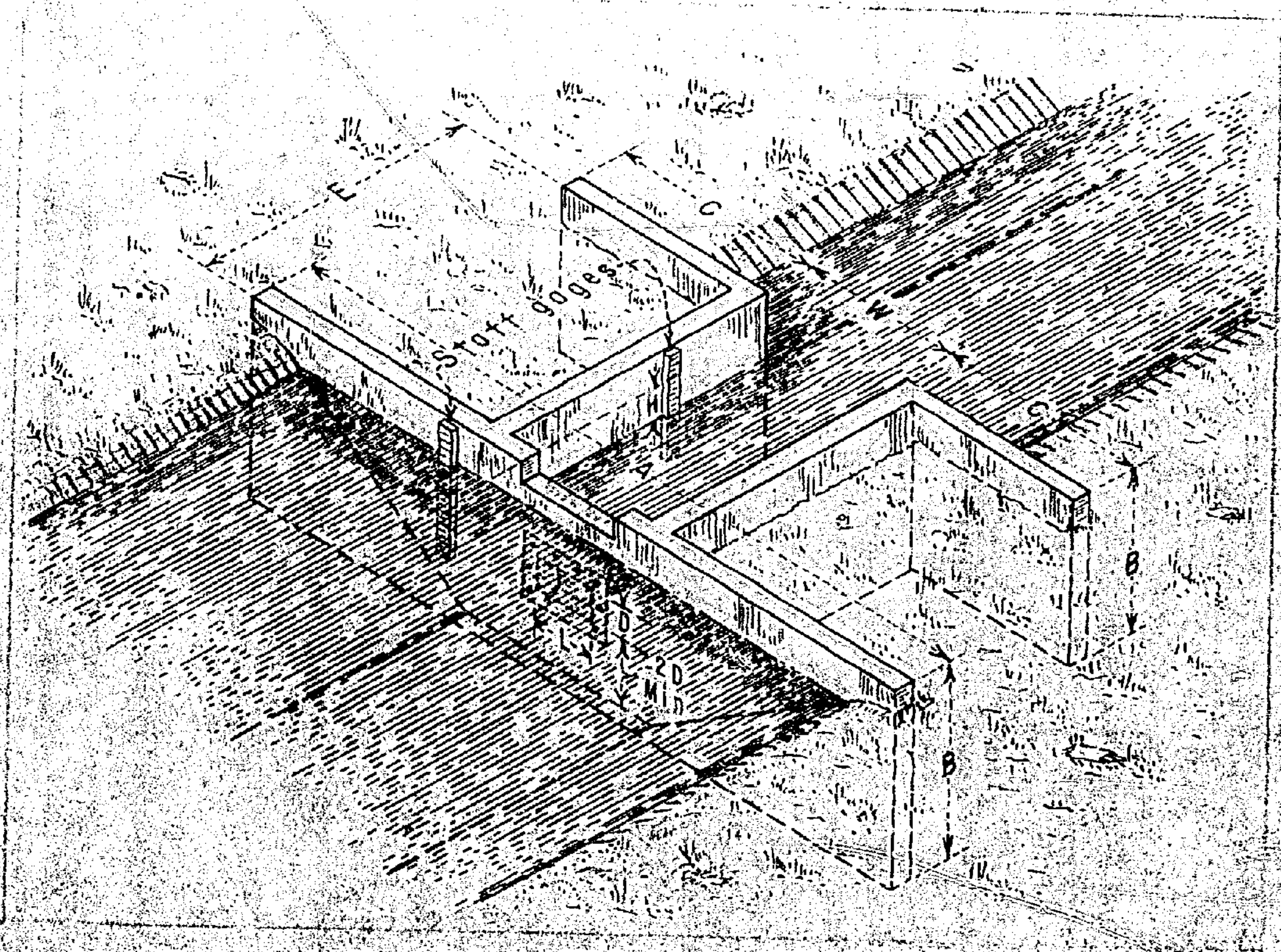

Figure 14. - Submerged orifice structure from upstream viewpoint. Dimensions refer to table 29.

36. Suitable dimensions for standard submerged rectangular orifices. The most suitable dimensions for standard submerged rectangular orifices are those in which the height is considerably less than the length. This is due to the fact that the ratio of depth to width of irrigation canals and laterals is generally small.

Convenient dimensions for submerged orifices are listed below:

No.	Height	Width	Area
	Ft.	Ft.	Sq. Ft.
1	0.25	1.0	0.25
2	0.25	2.0	0.50
3	0.25	3.0	0.75
4	0.50	1.0	0.50
5	0.50	1.5	0.75
6	0.50	2.0	1.00
7	0.50	2.5	1.25
8	0.50	3.0	1.50
9	0.75	1.333	1.00
10	0.75	1.666	1.25
11	0.75	2.000	1.50
12	0.75	2.333	1.75
13	0.75	2.666	2.00

These give orifices varying in area from 0.25 to 2.0 square-feet in intervals of 0.25 square-foot.

Where possible an orifice of 1 square-foot area should be chosen, as the unit area simplifies the discharge computation somewhat and will give discharges ranging from 0.0 to nearly 3.5 second-feet under heads varying from 0.0 to 0.5 foot. However, the size of the orifice selected will necessarily be determined by the quantity of water to be measured and the available fall that can be utilized therefor.

37. Formulae for standard submerged rectangular orifice discharge. The formula for computing the discharge of the standard submerged rectangular orifice, the velocity of approach being insignificant, is as follows:

$$Q = 0.61 \sqrt{2gH} \; A \qquad (23)$$

in which Q = discharge in second-feet, velocity of approach neglected

76

g = acceleration due to gravity (32.2 feet per second per second)

H = measured head on the orifice in feet, being equal to the difference in elevation of the water surface on the upstream side of the orifice and the water surface on the downstream side thereof, and

A = The area of the orifice in square feet.

When the velocity of approach is appreciable the following formula should be used for the computation of the discharge:

$$Q' = 0.61 \sqrt{2g(H+h)} \quad A \qquad (24)$$

where Q' = discharge in second-feet, the velocity of approach being taken into consideration.

g = acceleration due to gravity (32.2 feet per second per second)

H = the measured head on the orifice, in feet, being equal to the difference in elevation of the water surface on the upstream side of the orifice and the water surface on the downstream side thereof

h = the head due to velocity of approach, in feet, and

A = the area of the orifice in square feet

38. Velocity of approach in submerged orifice measurements. So far as practicable, submerged orifices should be so installed and maintained as to make the velocity of approach negligible, but where this is impracticable appropriate corrections therefor should be made.

It should be borne in mind that neglecting moderate velocities of approach with low heads on the orifice produces relatively large errors, whereas neglecting comparatively high velocities of approach with large heads on the orifice produces relatively small errors.

The velocity of approach may be computed from the following formula:

$$v = Q \div A \qquad (25)$$

where v = the velocity of approach in feet per second

Q = the discharge in second-feet, and

A = cross-sectional area of leading channel in square feet

The approximate discharge may be computed by the orifice formula (23) or determined with the use of table 27 without velocity of approach, with sufficient accuracy for determining v for ordinary cases. Successive approximations may be used to determine v to any desired degree of accuracy for special cases.

Having determined the value of v, the velocity of approach head may be computed from the following formula:

$$h = 0.0156v^2 \qquad (26)$$

This velocity head, designated as h, should be added to the measured head, as indicated in formula (24) before computing the discharge by the formula or before taking from the discharge table 27.

39. Table 27 (See section 84) Discharge of standard submerged rectangular orifices. For convenience in determining the discharge of standard submerged rectangular orifices with negligible velocity of approach for commonly used heads and orifices areas, table 27 is provided.

In using the table for orifices where the velocity of approach is negligible, H in the table can be taken as the measured head. In using the table for orifices where the velocity of approach is not negligible, the velocity head computed by formula (26) must be added to the measured head. H in the table will be taken as the sum of these two heads.

40. Correction for suppression of contraction in submerged orifices. While it is deemed desirable to use the standard submerged rectangular orifice so far as conditions will permit, it may be necessary in some cases, for the purpose of avoiding accumulations of silt on the upstream side of the orifice, to suppress the bottom contraction by placing the lower side of the orifice at canal grade, and cases may now and then arise where it will be necessary to determine the discharge of submerged orifices that have also their side contractions suppressed.

The discharge coefficients where suppression exists are not well defined, and it is, therefore, undesirable to permit suppression except where unavoidable.

78

The approximate discharge of the standard rectangular submerged orifices listed in section 36 above with contractions partially suppressed, may be computed, the velocity of approach being negligible, by the following formula:

$$Q_1 = 0.61\ (1 + 0.15r)\ \sqrt{2gH}\ \ A \tag{27}$$

in which Q_1 = the discharge in second-feet of the suppressed orifice without velocity approach

r = the ratio of the suppressed portion of the perimeter of the orifice to the whole perimeter

and H, A, and g have the same significance as in formula (23).

For such submerged orifices discharging under conditions where the velocity of approach is not negligible, the approximate discharge may be computed by the following formula:

$$Q'_1 = 0.61\ (1 + 0.15r)\ \sqrt{2g\ (H + h)}\ \ A \tag{28}$$

in which Q'_1 = the discharge in second-feet of the suppressed orifice with velocity of approach

r = the ratio of the suppressed portion of the perimeter of orifice to the whole perimeter

and H, A, g, and h have the same significance as in formula (24)

By comparison of formula (27) to formula (23) and formula (28) to formula (24) the following relations are derived:

$$\frac{Q_1}{Q} = \frac{Q'_1}{Q'} = (1 + 0.15r) = C \tag{29}$$

in which Q_1, Q'_1, Q, Q', and r have the same significance as in formulas (23), (24), (27), and (28), and C is a constant equal to 1 + 0.15r. It follows that C applied as a coefficient to Q or Q' will give Q_1 or Q'_1, respectively.

41. Table 28. (See section 84) This table gives coefficients, which applied to a discharge given by table 27 will give the discharge of the same orifice suppressed on the bottom alone or on the bottom and two sides. For an orifice constructed as a suppressed orifice or one in which silt has collected sufficiently to effect suppression, the

discharge should be corrected by means of this table.

First, the discharge without suppression should be taken from table 27, and then multiplied by the proper coefficient taken from table 28.

An illustration follows: Suppose it is desired to find the discharge of a standard submerged rectangular orifice 0.5 feet high by 2.5 feet wide with bottom and side suppressions under a head of 0.18 foot. For an area of 1.25 square feet (= 0.5 x 2.5) and a head of 0.18 foot, table 27 gives a discharge of 2.593 second-feet. For a height, d, of 0.5 foot and a length, l, of 2.5 feet with bottom and sides suppressed, table 28 gives a coefficient of 1.09. Then 2.593 x 1.09 = 2.826 second-feet, the discharge desired.

42. Construction and setting of submerged orifices. Submerged orifice boxes should be substantially constructed of lumber or concrete. The orifice box should be of sufficient length to extend downstream from the orifice wall far enough to still the water before it passes back into the earth channel below, or the channel should be suitably lined downstream from the orifice wall to offer such protection. The floor of the box should be depressed below the canal grade to form a stilling pool, and the floor and sides should be set at distances from the orifice opening of not less than twice the least dimension of the orifice. A flash board may be placed at the lower end of the orifice box to secure submergence of the orifice, but the box must have sufficient length in such a case to prevent disturbance in the water issuing from the orifice. The orifice wall should be set truly vertical and should reach only to the maximum water level so as to form an overflow in case of trouble. Wing walls or cut-off walls should be provided, both at the upper end and the lower end of the orifice box, for the purpose of preventing erosion of the canal banks and leakage of water around the structure.

Figure 14 [1] and table 29 provide recommended dimensions for a wooden or concrete submerged-orifice structure.

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(1) Bulletin 588, University of California Agricultural Experiment Station.

TABLE 29 - TYPICAL SUBMERGED ORIFICE BOX SIZES AND DIMENSIONS

Size of Orifice Height D Inches	Size of Orifice Length L Inches	Height of Structure B Feet	Width of Headwall A Feet	Length E Feet	Width W Feet	Length of Downstream Wingwall, C Feet
3	12	4.0	10.0	3.0	2.5	2.0
3	24	4.0	12.0	3.0	3.5	2.0
6	12	5.0	12.0	3.5	2.5	3.0
6	18	5.0	14.0	3.5	3.0	3.0
6	24	5.0	14.0	3.5	3.5	3.0
9	16	6.0	14.0	3.5	3.0	3.0
9	24	6.0	16.0	3.5	3.5	3.0

43. Commercial adjustable submerged orifices. There are available on the market adjustable submerged orifice gate structures fully equipped with stilling wells and staff gages for the measurement of water. These orifice structures bear with them, calibration curves which apply to the particular assembly alone when assembled and installed as specified in the manufacturers drawings. Inasmuch as the coefficient of discharge varies considerably the calibration curves should be followed rather than computed discharge from head-area determinations.

44. Constant Head Adjustable Submerged Orifices. The Bureau of Reclamation has developed what is known as a constant head orifice turnout which replaces the common turnout gate - weir combination. This device was designed to measure irrigation water accurately yet without the excessive amount of adjustment and walking usually incident to the gate - weir combination.

The structure consists essentially of two gates, the adjustable orifice gate and the turnout gate placed on the upstream side and downstream side of a stilling pool, respectively, which is a part of the turnout.

Two sizes of orifice gates are used, the 18-inch by 24-inch and 24-inch by 30-inch gates. These gates are used in single barrel and double barrel turnouts. Figure 15 illustrates a single barrel turnout.

The orifice is designed to operate at 0.2 feet effective head, which is adjusted by the turnout (downstream) gate after the orifice gate is

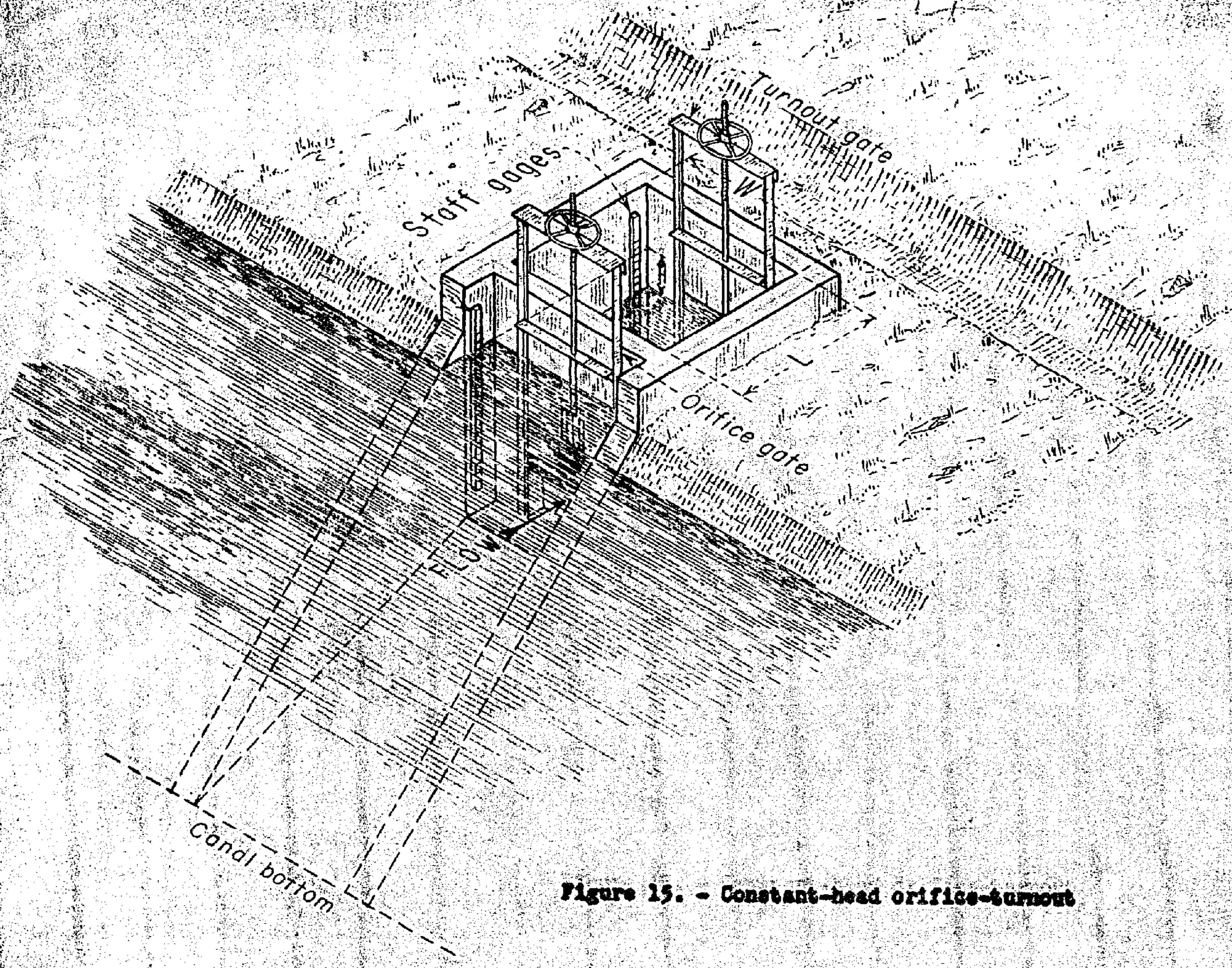


Figure 15. - Constant-head orifice-turnout

opened to a height determined from tables compiled for various discharges and gate openings. Details of this device are shown on Bureau drawings 40-D-3672 and 40-D-3673.

(Calibration tests are now being performed on 1 to 2 scale hydraulic models of this measuring device and operation tables will be prepared for insertion in this manual. Tables 30 to 33 inclusive are reserved for this purpose.)

CHAPTER V - CURRENT METER GAGING STATIONS

45. Use of current meter stations v. weirs, Parshall flumes or other measuring devices. Where the quantity of water to be measured is large and the available fall is small, the use of current meter stations is advisable. Where the quantity of water is small and extremely heavily laden with silt and the fall and depth of flow adequate, the use of the current meter station may be the most feasible. However, where it is essential to keep the loss of head at a minimum during high flow and where the depth of flow is insufficient for use of the current meter, the Parshall flume is recommended as it is essentially self-cleaning for a wide range of flow. In the case of large quantity of flow, current meter stations should be used where cost of operations of such stations is more economical than the construction of weirs, Parshall flumes or other devices. Their use should be reduced to the minimum, however, as their operation is comparatively expensive and the results are relatively unsatisfactory.

The discussion of current meter gaging stations and operational procedure offered herein is brief but is intended to be sufficient for the average irrigation water measurement problem. For extraordinary conditions the reader is referred to "Stream-Gaging Procedure, A Manual describing methods and practices of the Geological Survey" published as Water-Supply Paper 888 by the Geological Survey, United States Department of the Interior. That publication is generally recognized as an authoritative manual throughout the practice.

46. Selection of current meter stations. A current meter station should be located in a straight uniform stretch of canal with smooth banks and bed of permanent nature, so far removed from turnouts, drops, and checks that the relation of discharge to gage height will not be disturbed by these features. In many canals these conditions are difficult to find in combination and unusual care has to be taken to obtain a station that will give good results. Due to the shifting nature of river and canal beds frequent current meter measurements may be necessary. Sand shifts may occur frequently, often daily. In order to maintain the

84

gage-discharge relationship at stations on such streams, current meter measurements may be necessary two or three times weekly or perhaps daily, where the importance of equitable water distribution justifies such action. "Rating sections" consisting of a lined section of the channel located in a straight stretch of the canal may in many cases insure a meter station of unvarying dimensions where the silt problem is not serious. Such a section is shown in figure 16.

47. <u>Types of current meter measurements and current meter station equipment</u>. Current meter discharge measurements are classified according to the type of equipment used and the nature of the station site as follows:

(a) Wading measurement

(b) Cableway measurement

(c) Bridge measurement

(d) Boat measurement

(e) Measurement through ice cover

Types (d) and (e) above are not commonly used in irrigation practice and will not be discussed further in this manual. Figure 16 illustrates a typical bridge-type current meter station.

The essential features of a current meter station are a gage, a bench mark, fixed measuring points in the channel cross-section, and a stay line to hold the meter in the measuring plane or cross-section when the velocity is high and the water deep.

Water stages may be obtained by systematic observations of a nonrecording gage or by a water-stage recorder. The types of gages most commonly used in irrigation water are the graduated enameled vertical staff gage, hook gages, and float gages. The standard staff gage adopted by the Bureau of Reclamation is shown in figure 4. Water-stage recorders have advantages over staff gages read intermittently by attendants. Some of the more important are:

(a) In streams having daily fluctuation due to power regulation or other causes, continuous records insure the most accurate means of determining the daily mean gage height

Figure 16. Current meter station on canal. Bridge for measuring points and sheltered stilling well for automatic water-stage recorder are shown. View is downstream.

26

(b) Maximum and minimum stages are definitely recorded.

(c) A continuous record of stage is necessary to avoid inaccuracies in the computed discharge of streams subject to rapid fluctuation by artificial regulation.

(d) Water-stage recorders make practicable the obtaining of records at points on streams where local observers are not always available.

The installation, operation and inspection of water-stage recorders are among the more frequent duties of the irrigation system operator. The gage at any station on a canal, river or other channel must have its datum plane below the lowest stage of the stream and be sufficient in length to provide for the highest stage of the stream. It must be constructed in a position as to be connected to the flow of the stream at all stages, and yet be accessible at all times. It must be substantially constructed for security and reliability. When the water-stage recorder is used, the staff gage should be placed near the stilling well to facilitate checking of the recorder. It is sometimes advisable to provide reference gages both inside and outside the stilling well.

A water-stage recorder should be installed above a stilling well, sometimes referred to as the recorder well, and should be well housed from the weather. The instrument should be enclosed in a shelter which may be continuously ventilated to prevent a relative humidity which would cause distortion of the chart paper. In this connection it is usually necessary to partition the recorder off from the stilling well to exclude moist air. In other situations it may be necessary to provide a case for the instrument to protect it from dust and insects.

For accurate operation of the water-stage recorder the well and shelter must be maintained in good repair, the intake pipe must be kept open, and the well protected against ice or detritus.

The normal procedure in the use of the water-stage recorder consists of the following operations:

(a) Checking the float and water elevation with the recorded elevation with the recorded elevation on the chart; adjusting recorder or float mechanism when necessary

(b) Periodic changing of recorder charts

(c) Filling the recorder pen or sharpening the pencil, as the case may be

(d) Oiling the instrument and appurtenances when necessary

(e) Winding, setting, regulating, and maintenance of the clock

(f) Inspection of intake pipe to recorder well; cleaning is necessary.

Probably the stopping of clocks has been the cause of more breaks in water-stage recorder recorders than all the other causes combined. However, negligence on the part of the operator or inspector must be guarded against. Engineers installing water-stage recorders should follow carefully the instructions accompanying the instrument. These instructions should be placed in a conspicuous place in the instrument case or shelter for use of the operator or inspector.

The Geological Survey has prepared a standard inspection and report form for operators and inspectors of recording gages to reduce the amount of negligence to a minimum. The reports contain the following questions which indicate minimum requirements of the inspection:

(a) Was the gage working properly when you reached it?

(b) What is the correct time by your watch?

(c) What is the clock time?

(d) What is the time by the pen or pencil?

(e) What is the outside or river-gage reading?

(f) What is the inside or well-gage reading?

(g) Have you marked pen or pencil time on the chart by raising the float?

(h) Did you remove old sheet and put on new one? At what time did you do this?

(i) If you did not remove sheet, did you correct setting of pen or pencil and clock?

(j) Did you wind clock? regulate it?

(k) Did you sharpen pencil or fill pen?

(l) Did you mark pen or pencil time on new sheet by raising the float?

(m) Have you filled blanks on old sheet according to instructions?

(n) Have you made sure that pen or pencil is down, sheet placed correctly, setscrew on drum fastened, and gage working correctly before leaving station?

(o) Have you filled all blanks on this sheet according to instructions?

(p) Remarks and questions:

The bench mark should be conveniently and permanently located and the elevation of the datum of the gage should be carefully referred to it.

The measuring points should be located in a cross section at right angles to the stream flow on a tagged wire stretched across the channel or on a bridge located at the station. Where the canal is shallow enough to permit of wading measurements, a tagged wire should be used to definitely establish the measuring points. This applies to the cableway method also. When measurements are made from a bridge permanent points should be established thereon. The measuring points should be permanently fixed and marked at equal intervals of from 2 to 10 feet depending upon the size of the stream or canal.

A stay-line wire or cable should be stretched across the canal at such a height and far enough upstream from the measuring section to hold the current meter in proper position, where necessary.

The type A crane, as shown in figures 18 and 19 is used for stream-flow measurements on bridges where current meter weights between 30 and 75 pounds are necessary. This crane is mounted on three wheels designed to hold the current meter and weight in a balanced position while

99

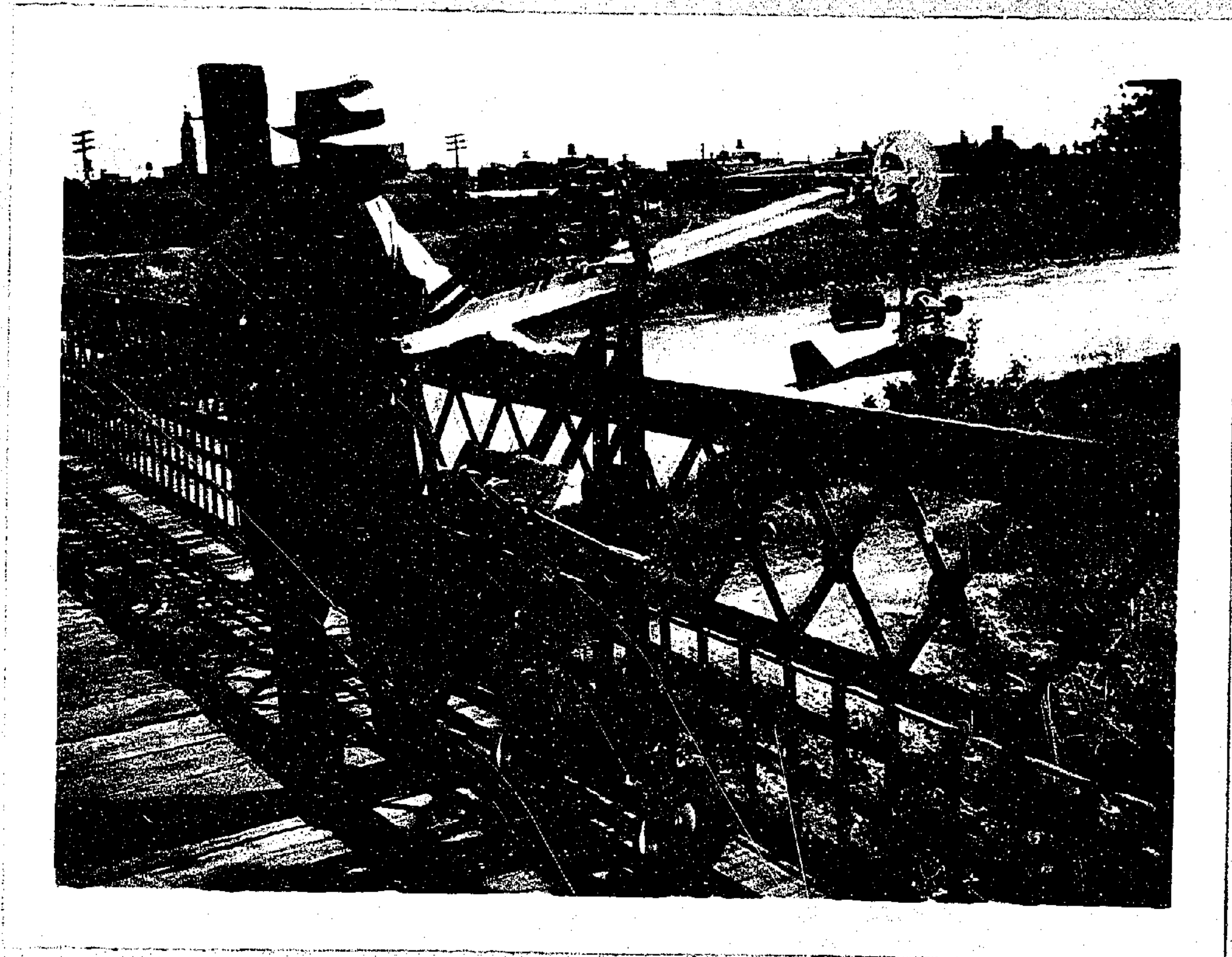


Figure 18. The Type A Crane and Current Meter Assembly in position on bridge.

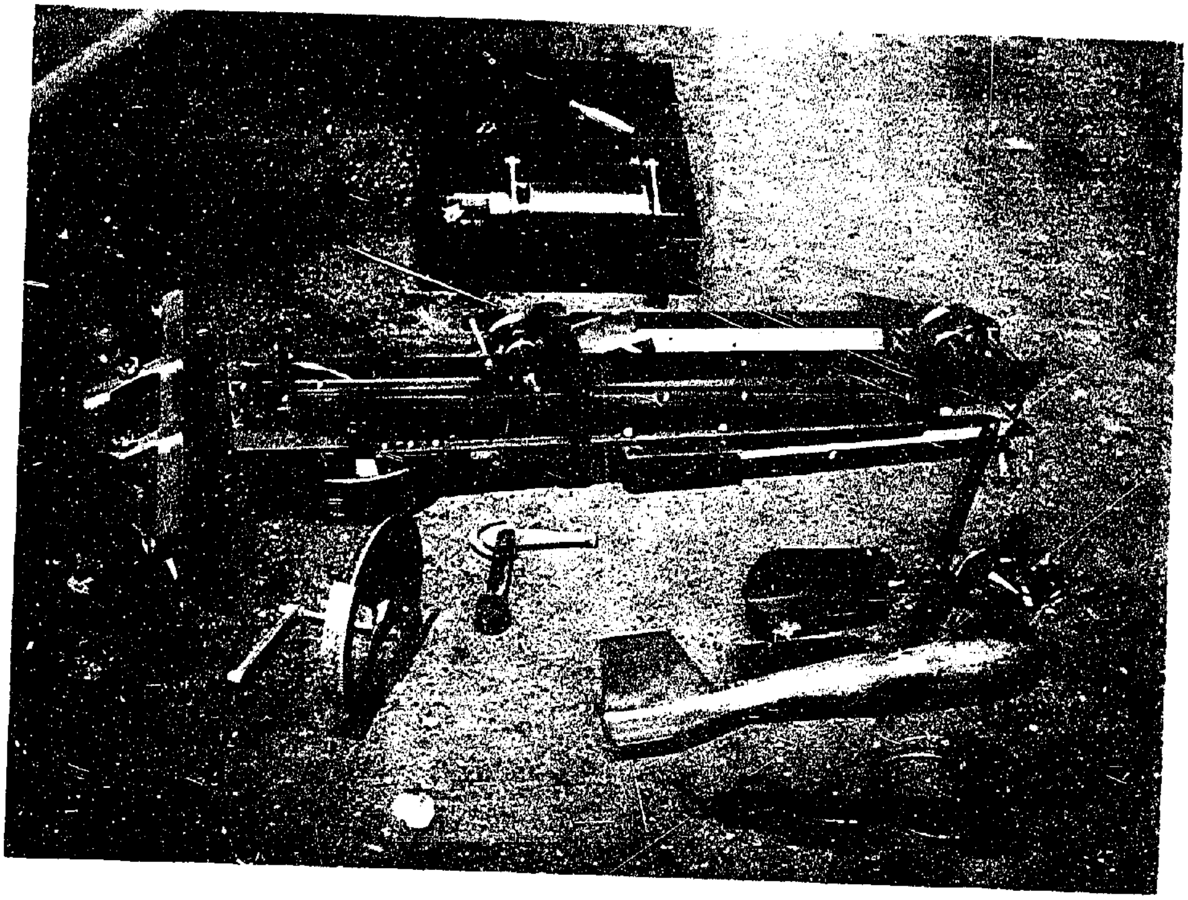


Figure 19. The Type A Crane folded ready for transportation.

moving between measuring points. For stream measurement the crane is tilted to lean against the bridge rail so the boom extends the meter and weight clear of the bridge. It may be folded into a compact unit for ease in transportation. The crane was designed by the U. S. Engineer Office at Cincinnati, Ohio and the U. S. Geological Survey at Columbus, Ohio. Improvements recently made on cranes used by the Bureau are described in Hydraulic Laboratory Report No. 181, "Construction of Type A Cranes, Stream Gaging Equipment."

48. Current meters. The essential features of all current meters are a wheel capable of rotation by impact of water and a device for determining the number of revolutions of the wheel. The relations between the velocity of the water and number of revolutions of the wheel per unit of time for various velocities are determined for each instrument by experiment at the Bureau of Standards laboratory at Washington, D. C., and are supplied in the form of an equation from which a rating table is compiled. An example is shown in figure 20. Each meter is calibrated for each of the types of suspensions with which it may be used. Several types of suspensions are shown in figure 21.

Since the accuracy of the instrument is greatly affected by dirt or injury, it should be returned to the laboratory for rating at least once a year and oftener if inaccuracy is suspected.

Meters are of two general classes, the propeller type with horiqontal axis and the cup type whose axis is vertical.

The Price meter, a cup-type instrument, was developed by the Geological Survey, United States Department of the Interior for use in its work and was adopted by the Bureau of Reclamation for irrigation water measurement purposes. These meters are of the conventional designs including the following general features: vanes to keep the wheel headed against the current, weights for sinking the meter, a cable for handling the meter, an electric or acoustic sounder for indicating the number of revolutions and connections from the meters to the sounding devices.

DEPARTMENT OF INTERIOR - BUREAU OF RECLAMATION

RATING TABLE FOR TYPE ______________ METER BR ______________

SUSPENSION ______________ RATED ______________

EQUATIONS: V = 2.16 N + 0.03 N<1.00

V = 2.18 N + 0.01 N>1.00

Limits of Actual Rating ________ to ________ ft. per sec.
at Bureau of Standards, Washington, D.C.

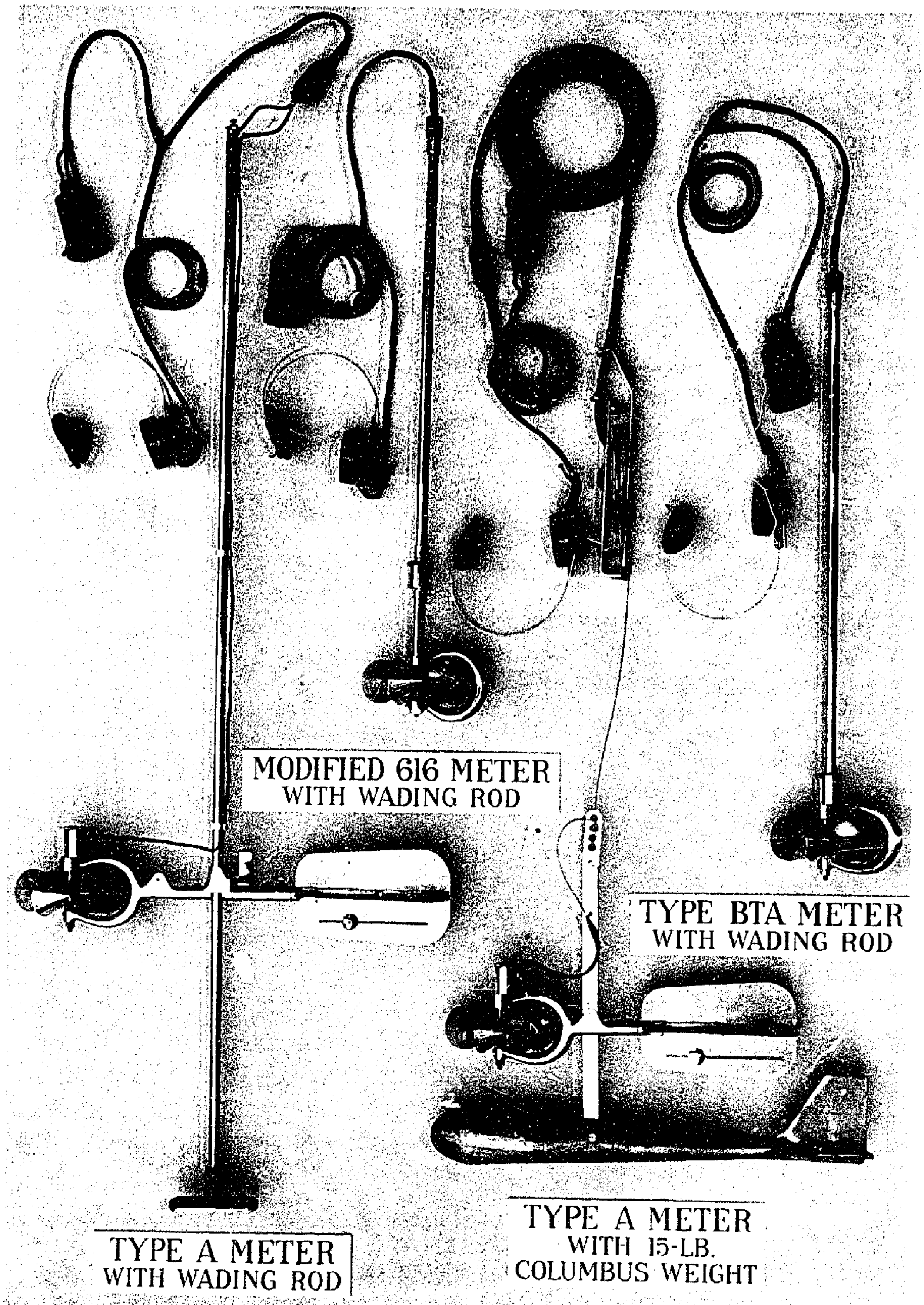
Condition of Meter

BR ____

Time, Seconds	VELOCITY IN FEET PER SECOND — Revolutions 3	5	7	10	15	20	25	30	40	Time, Seconds
40	0.192	0.300	0.408	0.570	0.840	1.11	1.38	1.65	2.19	40
41	0.188	0.294	0.399	0.557	0.821	1.08	1.35	1.61	2.14	41
42	0.183	0.287	0.391	0.544	0.801	1.06	1.32	1.57	2.09	42
43	0.181	0.281	0.382	0.533	0.784	1.03	1.28	1.54	2.04	43
44	0.178	0.276	0.373	0.520	0.767	1.01	1.26	1.50	1.99	44
45	0.175	0.270	0.367	0.510	0.749	0.989	1.23	1.47	1.95	45
46	0.170	0.265	0.358	0.499	9.734	0.970	1.20	1.44	1.91	46
47	0.168	0.259	0.352	0.490	0.719	0.950	1.18	1.41	1.87	47
48	0.164	0.255	0.345	0.479	0.704	0.931	1.16	1.38	1.83	48
49	0.162	0.250	0.339	0.471	0.691	0.911	1.13	1.35	1.79	49
50	0.160	0.246	0.332	0.462	0.678	0.894	1.11	1.33	1.76	50
51	0.157	0.242	0.326	0.453	0.665	0.877	1.09	1.30	1.72	51
52	0.155	0.237	0.322	0.445	0.652	0.862	1.07	1.28	1.69	52
53	0.153	0.233	0.315	0.438	0.641	0.844	1.05	1.25	1.66	53
54	0.151	0.231	0.311	0.430	0.630	0.829	1.03	1.23	1.63	54
55	0.149	0.227	0.304	0.423	0.620	0.816	1.01	1.21	1.60	55
56	0.147	0.222	0.300	0.417	0.609	0.801	0.993	1.19	1.57	56
57	0.144	0.220	0.296	0.408	0.598	0.788	0.978	1.17	1.55	57
58	0.142	0.216	0.291	0.402	0.589	0.775	0.961	1.15	1.52	58
59	0.140	0.214	0.287	0.395	0.579	0.762	0.946	1.13	1.49	59
60	0.138	0.209	0.283	0.391	0.570	0.749	0.931	1.11	1.47	60
61	0.136	0.207	0.278	0.384	0.561	0.738	0.916	1.09	1.44	61
62	0.134	0.205	0.274	0.378	0.553	0.728	0.900	1.08	1.41	62
63	0.134	0.201	0.270	0.373	0.544	0.715	0.888	1.06	1.40	63
64	0.132	0.198	0.265	0.367	0.535	0.704	0.875	1.04	1.38	64
65	0.129	0.196	0.263	0.363	0.529	0.695	0.862	1.03	1.36	65
66	0.127	0.194	0.259	0.358	0.520	0.684	0.849	1.01	1.34	66
67	0.127	0.192	0.255	0.352	0.514	0.676	0.836	1.00	1.32	67
68	0.125	0.190	0.252	0.348	0.507	0.665	0.825	0.983	1.30	68
69	0.123	0.186	0.248	0.343	0.499	0.656	0.812	0.970	1.28	69
70	0.123	0.183	0.246	0.339	0.492	0.648	0.801	0.957	1.26	70
	3	5	7	10	15	20	25	30	40	

Time, Seconds	VELOCITY IN FEET PER SECOND — Revolutions 50	60	80	100	150	200	250	300	350	Time, Seconds
40	2.73	3.28	4.37	5.46	8.19	10.91	13.63	16.36	19.08	40
41	2.67	3.20	4.26	5.33	7.99	10.64	13.30	15.96	18.62	41
42	2.61	3.12	4.16	5.20	7.80	10.39	12.99	15.58	18.17	42
43	2.54	3.05	4.07	5.08	7.61	10.15	12.68	15.22	17.76	43
44	2.49	2.98	3.97	4.96	7.44	9.92	12.39	14.87	17.35	44
45	2.43	2.92	3.89	4.85	7.28	9.70	12.12	14.54	16.96	45
46	2.38	2.85	3.80	4.75	7.12	9.49	11.86	14.23	16.60	46
47	2.33	2.79	3.72	4.65	6.97	9.29	11.60	13.92	16.24	47
48	2.28	2.73	3.64	4.55	6.82	9.09	11.36	13.64	15.90	48
49	2.23	2.68	3.57	4.46	6.68	8.91	11.23	13.35	15.58	49
50	2.19	2.63	3.50	4.37	6.55	8.73	10.91	13.09	15.27	50
51	2.15	2.57	3.43	4.28	6.42	8.56	10.70	12.83	14.97	51
52	2.11	2.53	3.36	4.20	6.30	8.39	10.49	12.68	14.68	52
53	2.07	2.48	3.30	4.12	6.18	8.24	10.29	12.35	14.41	53
54	2.03	2.43	3.24	4.05	6.07	8.08	10.10	12.12	14.14	54
55	1.99	2.39	3.18	3.97	5.96	7.94	9.92	11.90	13.88	55
56	1.96	2.35	3.12	3.90	5.85	7.80	9.74	11.69	13.64	56
57	1.92	2.30	3.07	3.83	5.75	7.66	9.57	11.48	13.39	57
58	1.89	2.27	3.02	3.77	5.65	7.53	9.41	11.23	13.16	58
59	1.86	2.23	2.97	3.70	5.55	7.40	9.25	11.09	12.94	59
60	1.83	2.19	2.92	3.64	5.46	7.28	9.09	10.91	12.72	60
61	1.80	2.15	2.87	3.58	5.37	7.16	8.94	10.73	12.52	61
62	1.77	2.12	2.82	3.53	5.28	7.04	8.80	10.56	12.31	62
63	1.75	2.09	2.78	3.47	5.20	6.93	8.66	10.39	12.12	63
64	1.72	2.05	2.73	3.42	5.12	6.82	8.52	10.23	11.93	64
65	1.69	2.02	2.69	3.36	5.04	6.72	8.39	10.07	11.75	65
66	1.67	1.99	2.65	3.31	4.96	6.62	8.27	9.92	11.57	66
67	1.64	1.96	2.61	3.26	4.89	6.52	8.14	9.77	11.40	67
68	1.62	1.93	2.57	3.22	4.82	6.42	8.02	9.63	11.23	68
69	1.60	1.91	2.54	3.17	4.75	6.33	7.91	9.49	11.06	69
70	1.57	1.88	2.50	3.12	4.68	6.24	7.79	9.35	10.91	70
	50	60	80	100	150	200	250	300	350	

Figure 20. - Typical current meter rating table



CURRENT METER SUSPENSIONS

In May 1942, the repair of current meters belonging to the Bureau of Reclamation was transferred from the Division of Field Equipment of the Geological Survey in Washington, D. C., to the hydraulic laboratory of the Bureau of Reclamation in Denver, Colorado. It was discovered that seven different types of Price meters, many being obsolete, were being used in the field. In 1944, a program was formulated whereby the Bureau current meter equipment could be modernized and standardized to keep pace with the developments in the Geological Survey.

Three standard meters have been adopted by the Bureau. These are the type A meter with the Columbus type weights, the modified 616 meter, and the BTA meter, all shown on figure 21.

The modified 616 meter was developed from a standard type 616 by removing the acoustical clapper and inserting an electrical contact and gear to indicate every fifth revolution. The gear is the same as used in the 623-type meter, no longer used. The diaphragm was replaced by an electrical contact which completes a circuit with the wading rod as the other side. By using headphones attached through a special connector at the top of the wading rod, the meter can be used in the same manner as a type A meter. This new meter is called the modified 616 meter which designates the tailless yoke and the conversion from acoustic to electrical counter.

When field tests were conducted on the modified 616 it was found that the long slender drive shaft of the acoustic meter was subject to vibration and wear, and the 623-type pivot and bearing were not sufficiently sturdy to withstand the hard usage in the hands of relatively inexperienced personnel.

To retain the excellent qualities of the type A current meter, the tailpiece and hanger support were removed from the meter and a new contact chamber and cap designed to which the wading rod can be attached. Electrical connection between the meter and the headphones is made through the wired wading rod designed as an improvement in the modified 616 wading rod. This meter, the BTA meter, has the acceptable features of the type A and the modified 616 meter.

The wading rod is a rod wired for current identical to modified 616. The BTA meter has the same pivot, hub assembly and shaft as the type A, which obviates the necessity to maintain two sets of repair parts as heretofore. The parts on the type A and the BTA are interchangeable except for the yoke and the contact chamber.

The development of the new types of meters is covered in detail in Hydraulic Report No. 165, "Repair and Rating of Current Meters, Denver Hydraulic Laboratory, dated February 15, 1945."

49. Care of the meter. The current meter must receive the best of care when being used and when being transported to insure accuracy of velocity measurements. Particular care should be taken when observations are being taken near bridge piers and abutments, when floating drift or ice are likely to be encountered and when soundings are being taken at irregular or unknown sections with the meter suspended on the measuring line.

Much damage to meters has occurred due to improper packing and careless handling in their transportation. Meters should be transported in substantial wooden cases properly fitted to prevent damage to the delicate parts of the instruments.

50. General Precautions. Accuracy of discharge measurements may be maintained by adherence to the following general precautions:

(a) Test the meter immediately before and after each discharge measurement with a spin test in quiet air, to insure proper free action.

(b) Inspect the meter at frequent intervals to determine whether it is operating freely, and holding to its rating.

(c) The cross section of the stream should be divided up into a sufficient number of areas in order to insure that the velocity and depth measurements will accurately determine the total discharge.

(d) The stop watch should be checked frequently.

(e) The period of observation on low and irregular velocities should be extended to obtain a more accurate average.

51. <u>Methods of measurement.</u> Soundings, either with a meter or with a special sounding line and weight, should be made at the permanent measuring points. The mean velocity at each of these measuring points should then be determined by means of the current meter, in accordance with one of the approved methods of determining mean velocities.

52. <u>Methods of determining mean velocities</u>. The following general methods are used to determine mean velocities in a vertical line with a current meter:

(a) Two-point method
(b) Six-tenths-depth method
(c) Vertical velocity-curve method
(d) Subsurface method
(e) Integration method
(f) Two-tenths method
(g) Three-point method
(h) One-point continuous method

The two-point method consists of taking the velocity at 0.2 and that at 0.8 of the water depth and obtaining half the sum.

The six-tenths-depth method consists of taking the velocity at 0.6 of the water depth.

The vertical velocity curve method is used by taking the velocities at equal vertical intervals of 0.5 of a foot or more and obtaining their arithmetical mean, or finding the mean value from a curve derived by plotting the measurements on cross-section paper.

The subsurface method is performed by taking the velocity near the water surface and using from 0.85 to 0.95 of the result, depending on the depth of water, its velocity, and the nature of the stream or canal bed.

The integration method is performed by observing the velocity in the vertical line by slowly and uniformly lowering and raising the meter throughout the range of water depth one or more times.

The two-tenths method, the three-point method and the one-point method are special methods based on relationship previously established for the section between the true discharge and observed velocity by these methods. Generally, they are reliable for sections which undergo no serious changes because of erosion, silting or other deformation. These methods are treated in detail in Geological Survey Water Supply Paper 888.

Of the methods cited herein the first two are most used in canal work.

53. Methods of computing discharge measurements. There are two important methods of computing discharges from measurements made by current meters. Both of these methods are based on determining the discharges of the elementary areas between the measuring points or verticals and taking their sum.

In one of these methods the discharge is computed separately for each elementary area on the assumption that both the velocity and the water depth vary uniformly from one measuring point or vertical to another. This is commonly termed the "straight line" or "rectilinear" method, and the formula for computing the discharge of the elementary area is as follows:

$$q = \left(\frac{V_a + V_b}{2}\right)\left(\frac{a + b}{2}\right) L \qquad (30)$$

in which

a and b = the water depths in feet at two adjacent measuring points

V_a and V_b = the respective mean velocities in feet per second at these points

L = the distance in feet between the points

and q = the discharge in second-feet for the elementary area

Formula (30) is well suited to computing discharges in canals conforming in cross section to their original trapezoidal or rectangular dimensions.

In another method the discharge is computed for consecutive pairs of elementary areas on the assumption that the velocities and the water depths for three consecutive measuring points each lie on the arc of a parabola. This method is known as "Simpson's parabolic" rule, and the formula for computing the discharge for each pair of elementary areas is as follows:

$$q' = \left(\frac{V_a + 4V_b + V_c}{6}\right)\left(\frac{a + 4b + c}{6}\right) 2L \qquad (31)$$

in which

a, b, and c = the water depths in feet at three consecutive measuring points

V_a, V_b and V_c = the respective mean velocities in feet per second at these points

L = the distance in feet between the consecutive points, and

q' = the discharge in second feet for the pair of elementary areas.

Formula (31) is more particularly applicable to river channels and old canals that have cross sections conforming in a general way to the arc of a parabola or to a series of arcs of different parabolas.

The method of computation of discharge by formula (30) is illustrated in figure 22.

54. Range of discharge measurements. The discharge measurements of a canal at a current meter station should be taken at sufficient intervals of gage heights to insure accuracy in the preparation of velocity, area, and discharge curves. Inasmuch as water is usually turned into the canals gradually in the beginning of each irrigation season, it is possible at that time to get well-distributed measurements for the condition of the canal at that season.

The canal bed at a well-selected current meter station is generally permanent in character and a permanent rating curve for the canal could be made were it not for the fact that increased vegetable growth in the canal and on its banks during the irrigation season, together with accumulations of silt, decrease the discharge capacity for all gage

7-675
(Aug. 1920)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CURRENT METER NOTES

Date Sept. 17, 1909, 10:30 a.m. Stream Power Canal
Party E. S. Fuller Locality Spanish Fork, Utah
Meter No. 400 Gage height, beg. 2.80, end 2.80, mean 2.80
Total area 19.0 Mean velocity 5.66 Discharge 107

OBSERVATIONS					COMPUTATIONS						
Dist. from initial point	Depth	Depth of observat.	Time in seconds	Revolutions	Velocity: At point	Velocity: Mean in vertical	Velocity: Mean in section	Mean depth	Width	Area	Discharge
4.2	0	Est.	--	--	3.49	3.49	--	--	--	--	----
5.6	1.4	0.8	46.0	100	4.98	4.98	4.24	0.7	1.4	0.98	4.2
7.0	2.8	.56	34.4	100	6.64		5.45	2.1	1.4	2.94	16.0
		2.24	44.0	100	5.20	5.92					
8.0	2.8	.56	35.2	100	6.49		6.10	2.8	1.0	2.80	17.1
		2.24	37.8	100	6.05	6.27					
9.0	2.8	.56	36.2	100	6.32		6.14	2.8	1.0	2.80	17.2
		2.24	40.0	100	5.72	6.02					
10.0	2.8	.56	37.4	100	6.12		5.94	2.8	1.0	2.80	16.6
		2.24	40.8	100	5.61	5.86					
11.0	2.8	.56	38.0	100	6.02		5.75	2.8	1.0	2.80	16.1
		2.24	43.4	100	5.27	5.64					
12.4	1.4	.8	47.0	100	4.87	4.87	5.26	2.1	1.4	2.94	15.4
13.8	0	Est.			3.41	3.41	4.14	.7	1.4	.98	4.1
							5.62			19.04	106.7

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heights during the latter part of the irrigation season. This fact must be taken into consideration in computing the quantity of water carried by a canal during the irrigation season. If the canal is cleaned during the season, the relation of discharge to gage height is again disturbed. The changing relations of discharge to gage height is the chief source of errors and difficulties in irrigation canal hydrography.

Many of these difficulties have been averted in some canal sections by the installation of what is known as "rating sections" or lined sections in which the cross section is not changed by vegetal growth. In many such installations the silt problem has been encountered still, where the velocities are low enough to deposit silt in the section.

55. Daily gage heights. In order to determine the quantity of water carried by a canal at a current meter station it is necessary to read the gage at least twice daily and additionally at such times as changes of stage are made in the canal. These readings should be taken by the canal riders while on their daily rounds. The gages should be read accurately, generally to the nearest hundredth of a foot. The gage should be read carefully also by the hydrographer both before and after taking a current meter measurement. Water stage recorders obviate the necessity of such numerous readings.

56. Computation of discharges. The current meter measurements are made applicable for all gage heights by plotting curves drawn on cross-section paper. To construct these curves, the discharges of the canal in second-feet as computed from individual current meter discharge measurements, the corresponding mean velocities, in feet per second, and the cross-sectional areas in square feet for each measurement are plotted as abscissas, each to a convenient scale, with the common gage height as ordinates.

As illustrated in figure 23, the most probable area curve is drawn through the area plottings, and from this the accuracy of the area computations and of the soundings are checked and, in case of a shifting channel, changes in the rating section are discovered.

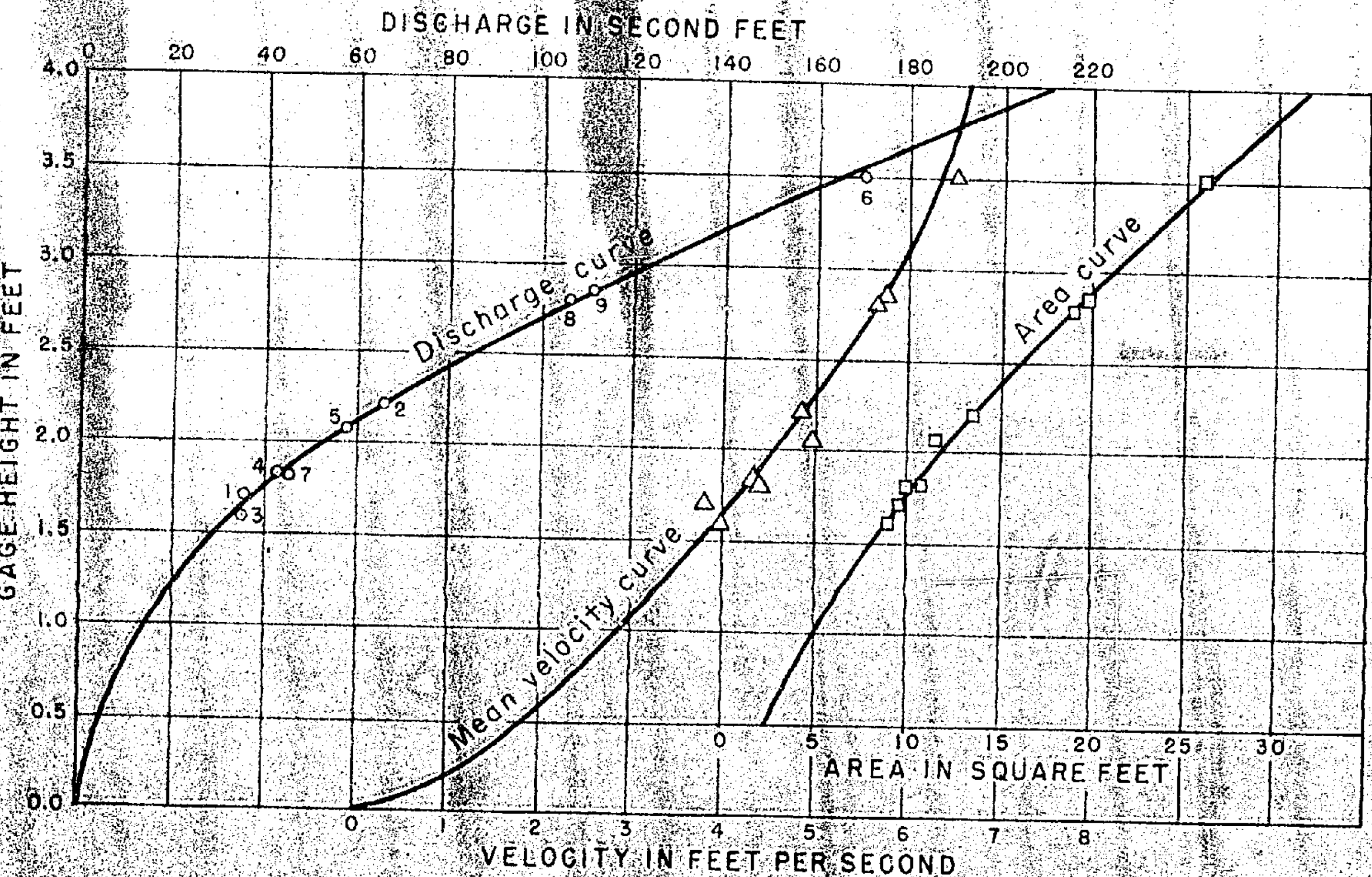

Figure 35. - Sample discharge, mean-velocity and area curves for a canal

The most probable velocity curve is drawn through the velocity plotting a graphic means of finding inaccuracies in the computations and noting disturbances in the velocity due to increased roughness of the channel from vegetable growths in the canal.

The discharge curve is then drawn through the discharge points on the cross-section paper, giving due weight to the various measurements and to products of the mean velocity and area abscissas for various gage heights throughout the range of canal depths. Where the conditions of flow of the canal have not been changed during the irrigation season, it will generally be comparatively easy to draw a satisfactory curve. Where, however, the relation of the discharge to gage height has been affected by vegetable growth or the introduction of other obstructions, these conditions must be given careful consideration and another curve drawn for that part of the irrigation season during which such conditions have existed. The discharge curve for these conditions will generally be parallel to the discharge curve for the earlier part of the irrigation season when the canal is clean. For the period during which the change is in progress the discharges must be estimated on the theory of proportion from the two curves constructed for the extreme conditions.

57. Rating table. From the rating curve the rating table may be prepared for each tenth or hundredth of a foot of gage height as the condition of accuracy may require, ranging from zero to the maximum height of water in the canal. In the case of canals affected by vegetable growth two such rating tables will be necessary, one applying to the early part of the irrigation season when the canal is clean and the other to the latter part of the irrigation season when the canal is in relatively poor condition. Daily discharges will also have to be estimated for the period in which the change in the canal is being affected. In case the canal is cleaned at any time during the irrigation season, this fact must be given consideration in preparing the necessary additional rating curves. A sample rating table is shown in table 34.

55. <u>Compilation of daily and monthly discharges.</u> By means of daily gage heights and the rating tables the daily discharges may readily be compiled, and adding these gives the monthly discharges and the total amount of water by the canal during the irrigation season.

TABLE 34 – SAMPLE RATING TABLE FOR BUREAU OF RECLAMATION POWER CANAL AT SPANISH FORKS, UTAH

Gage Height	Discharge	Difference	Gage Height	Discharge	Difference
Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.
					5.6
0.0	0.0		2.1	60.1	
		0.2			5.9
.1	0.2		2.2	66.0	
		0.5			6.2
.2	0.7		2.3	72.2	
		0.8			6.5
.3	1.5		2.4	78.7	
		1.1			6.8
.4	2.6		2.5	85.5	
		1.4			7.0
.5	4.0		2.6	92.5	
		1.7			7.2
.6	5.7		2.7	99.7	
		1.9			7.3
.7	7.6		2.8	107	
		2.1			8
.8	9.7		2.9	115	
		2.3			8
.9	12.0		3.0	123	
		2.5			8
1.0	14.5		3.1	131	
		2.7			8
1.1	17.2		3.2	139	
		3.0			9
1.2	20.2		3.3	148	
		3.3			9
1.3	23.5		3.4	157	
		3.5			9
1.4	27.0		3.5	166	
		3.8			9
1.5	30.8		3.6	175	
		4.1			9
1.6	34.9		3.7	184	
		4.4			9
1.7	39.3		3.8	193	
		4.7			9
1.8	44.0		3.9	202	
		5.1			9
1.9	49.1		4.0	211	
		5.4			
2.0	54.5				

105

CHAPTER VI- SPECIAL METHODS FOR OPEN CHANNELS

59. Introduction. The methods described in Chapters II to V, inclusive, are the common and most generally used methods of measuring irrigation water in ordinary irrigation water distribution systems in the United States. Situations may arise where it is not practicable to use the methods described heretofor and where meters and other comparatively accurate devices are also impracticable.

Of the methods described in this chapter the Clausen-Pierce weir gage and commercial meters are used to a limited extent in irrigation practice. Use of calibrated gates and sluices is sometimes made, particularly for large discharges. The control section method is used for approximate measurement of large quantities of flow.

The other methods briefly described herein may be used by engineers for computation of approximate discharges according to the special conditions attending, and the equipment and personnel available.

60. Float measurements. The discharge of a canal or stream may sometimes be approximately determined by use of surface floats for measuring the velocity and multiplying by the cross-sectional area of the flow.

A stretch of the canal, straight and uniform in cross section and grade, with a minimum of surface waves, should be chosen for the measurements. Surface velocity measurements should be made on a windless day, as even under the best conditions the floats often are diverted from a direct course between measuring stations by surface disturbances and cross currents.

The width of the canal should be divided into segments, and the average depth determined for each segment. The segments should be narrower in the outer thirds of the canal than in the central third. Float courses should be laid out in the middle of the strips defined by the segments. The velocities of the floats in these strips, after being adjusted to approximate the mean velocity of the strip, multiplied by the area of the strip will give the flow. Accordingly, the sum of the discharges of the individual strips across the canal will give the total discharge.

It has been found that for regular channels flowing in a straight course under favorable conditions the mean velocity of a strip in the channel is approximately 0.85 of the surface velocity of that strip. The value is an average of many observations and it should be noted that for any particular channel it may be as low as 0.80 or as high as 0.95. Therefore, this method is applicable only as an approximate method and should be used only with the above mentioned difficulties in mind.

The rod or tube float consisting of a wooden rod, square or round in section of width or diameter from 1" to 2" proportional to length for strength against rough field use, is used extensively in India. It is a reasonable assumption that the velocity of a rod float, extending from the water surface to the bottom of a channel, will very closely represent the mean velocity of the water in that proximity. It has been found that the velocity of the rod equals the mean velocity of the water in the vertical when the length of the immersed portion is from 0.91 to 0.97 of the depth of the vertical, 0.94 being adopted as a standard average. The peripheral areas whose mean velocities are not measured by the rods may be assumed to be, with good accuracy, 2/3 to 3/4 of the mean velocity of the individual areas above.

The method of rod floats may be applied to canals of unusually straight stretch, regular and uniform cross-section and grade. Where these conditions exist and the flow is free of cross currents and eddies discharge measurements may be made with a high degree of accuracy.

This method has several limitations and defects: a large party is required to assist in conducting the measurements; it is difficult to control the course of the floats; and the rods may be easily fouled by a slight irregularity in the channel bed.

61. <u>The pitot tube and its use</u>. The pitot tube is an instrument consisting essentially of a small bent tube, which if immersed vertically in water with the bent part under water and pointed directly upstream into the current, will measure the velocity head ($V^2/2g$) in the vertical or main portion of the tube.

The pitot tube can be used to measure velocities in canals if the velocities are great enough. In this connection it is often possible to select a pitot tube traverse station at a drop, chute, overfall crest, or other station of a canal where the velocity is comparatively high. It should be noted that a small error in reading of the pitot tube head in a small velocity will lead to a much larger error in discharge computations than the same error in reading in a high velocity stream. Therefore, this method of determining the mean velocity of irrigation water in canals should be restricted, generally, to high velocity sections.

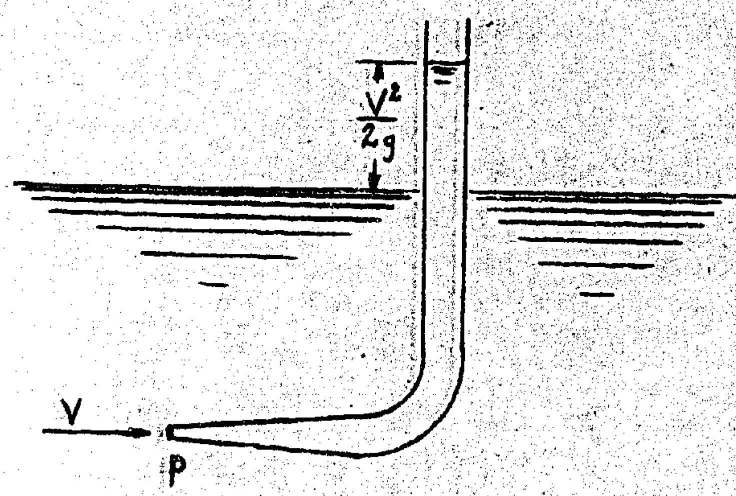

Figure 24 - Diagram of Pitot Tube

The velocity traverse with the pitot tube may be made in the same manner as with the current meter. The use of the pitot tube is generally restricted to pipes and other pressure conduits where its simplicity and small size are particularly favorable.

Tubes have been designed and used whereby the velocity head is measured directly without the application of a correction factor.

These pitot tubes are described in the American Society of Mechanical Engineers publication "Fluid Meters" fourth edition, 1937. With the use of these tubes the velocity can be computed by the equation:

$$V = \sqrt{2gh} \qquad (32)$$

where V = velocity in feet per second

g = 32.2 feet per second per second

and h = observed velocity head on the pitot tube, in feet.

The most common pressure conduit is the circular pipe. For a constant rate of flow the velocity varies from point to point across the stream, gradually increasing from the walls of the pipe toward the center. The mean velocity is obtained by dividing the cross-sectional area of the pipe into a number of concentric rings and a central circle. Velocity observations are taken in the center of each of these sub-areas by the formula:

$$V\ (\text{ave}) = \sqrt{2g}\ (\sqrt{h})\ (\text{ave}) \qquad (33)$$

62. Salt-Velocity method. This method, devised by Professor C. M. Allen and E. A. Taylor, is based on the fact that salt in solution increases the electrical conductivity of water. The method has been successfully utilized in open channels of constant cross-section, although it is more generally used in measuring flow in closed conduits. In this method a quantity of salt solution is forced under pressure through a quick-closing pop valve into the stream and the average velocity is obtained by measuring the velocity of the solution as it moves along with the stream.

In determining the average velocity of the solution, a pair of electrodes is installed across each of two sections of the conduit or channel downstream from the valve through which the salt solution is introduced. The distance between them should be sufficient to insure accurate timing of the movement of the slug of solution between the pairs of electrodes. Each set of electrodes is energized by an electrical current and connected to a recording galvanometer which records current strength at the electrodes with respect to time.

The graph produced on the recording galvanometer will have two humps in the current strength, which indicate the passing of the slug of solution past each pair of electrodes. The distance on the graph between the center of the hump areas measured in seconds is the time required for the salt solution to pass from the upstream to the downstream electrode.

With the data thus observed the flow of the channel or conduit can be computed by the formula:

$$Q = \frac{A \times L}{T} \qquad (34)$$

where Q = the discharge in second-feet

A = cross-sectional area of the conduit or channel in square feet

L = Distance in feet between the pairs of electrodes, and

T = recorded time in seconds required for the slug of salt solution to pass between pairs of electrodes.

This method requires special equipment and personnel experienced in its use and is, therefore, relatively expensive.

63. Salt dilution method. This method consists of adding a concentrated solution of salt, strength known, to the stream and by chemical analysis determining its dilution after flowing a distance sufficient to insure complete mixture with the water in the stream. The solution must be added at a constant rate. No measurements of area or distance are required.

The weight of salt passing the sampling point per second must equal the sum of the weights of salt ordinarily carried by the stream and the weight of the salt added per second in the concentrated solution. This may be expressed in formula form:

$$WP + W'P' = (W + W')\,P'' \qquad (35)$$

where W = weight of water, in pounds, discharged per second

W' = weight of salt solution added per second

P = percentage, by weight of natural salt already in stream

P' = percentage, by weight, of salt in concentrated solution, and

P'' = percentage, by weight, of salt in sample after mixing.

The value of W' is determined as the concentrated solution is being added to the stream. The value of P, P', and P'' are determined by titration methods. W is, therefore, the only unknown in equation (35) and can be solved for directly.

This method is particularly applicable for measuring the discharge of turbulent streams where other methods are impracticable. Excessive quantities of salt are required on large streams and equipment required for dosing and sampling renders this method quite costly.

64. Color-velocity method. This method has been used in the measurement of flow of water of high velocity in open channels.[1] It consists of determining the velocity of a slug of dye or liquid coloring matter between two stations in the channel. This velocity, used as the mean velocity of flow, multiplied by the cross-sectional area of the flow gives the discharge.

Commercial fluorescein or potassium permanganate may be used as the coloring matter. Fluorescein, a red powder, produces greenish color when dissolved in slightly alkaline water. This distinctive color is easily visible in very dilute solutions. Potassium permanganate is a red dye not so easily detected by sight in diluted solution and must, therefore, be used in a much more concentrated solution. The concentration of these solutions should be determined by experiment before measurement observations are started.

The procedure for determining the velocity in the channel is as

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[1] Paper No. 2205, Entrainment of Air in Flowing Water, A symposium: Open Channel Flow at High Velocities, by L. Standish Hall.

follows: a small slug of dye or coloring matter contained in a light paper carton is instantaneously poured into the flow at the upstream station, manually. Time observations are made at the instant the dye is added and at the instant the center of the slug passes the downstream station. The mean velocity is computed from the mean time required for the slug of dye to traverse the course, and the length of the course.

This method has very definite limitations and drawbacks. Due to the entrained air in the surface of the water at high velocities and the attendant spray above the surface, detection of the position of the center of the colored slug may be difficult. Then, too, it may be uncertain whether the observed velocity is mean, or that of the surface.

65. __Slope-Area Method.__ This method of determining the discharge of a stream consists of gathering sufficient field data and substituting in the following formula:

$$Q = \frac{1.486}{N} AR^{2/3} S^{1/2} \qquad (36)$$

where Q = the discharge in second-feet

A = mean area of the channel cross-section in square feet

R = the mean hydraulic radius of the channel in feet

S = slope of the water surface = $\frac{\text{fall}}{\text{length of course}}$, and

N = a roughness factor depending on the character of the channel lining.

A straight course of the channel should be chosen, at least 200 feet in length and preferably 1000 feet if practicable. The course should be free of rapids, abrupt falls, sudden contractions or expansions.

The slope may be determined by dividing the difference in the average of the elevations of water surface at two or more gages at each end of the course by the length of the course. The gages, carefully referenced to a common datum plane, should be placed, one on each bank of the channel and one in the center of the stream, in stilling wells, if possible.

The hydraulic radius is defined as the area of the cross-section divided by the wetted perimeter of the cross-section. Where the channel or canal is of regular cross-section the area and the wetted perimeter will be constant throughout the course if the depths at the ends of the course are equal. In irregular channels, the area and the wetter perimeter at several stations will be required and a mean value used in computing the hydraulic radius.

The factor "N" is dependent on the character of the channel. It may vary from 0.010 where conditions approaching the ideal are maintained, to 0.06 for canals and rivers in bad order, having the channel strewn with stones and detritus or about one-third full of vegetation.

Inasmuch as the proper selection of the roughness Factor "N" for many streams is difficult and is at best an estimate the discharge determined by the slope-area method is approximate. Various hydraulic text books and hand-books provide tables to assist in the computations of discharges with the data procured in the field.

66. Computation of discharge over dams. Many overflow dams have been built across streams. The overflow can be computed by the general formula:

$$Q = CLH^{3/2} \qquad (37)$$

where Q = discharge in second-feet

L = length of the crest of the dam, in feet

H = head on the crest, in feet, and

C = coefficient dependent on the shape of the crest and the head.

Inasmuch as the shapes or profiles of dams and their crests vary greatly, the determination of the coefficients of discharge for the many types would be a difficult task. It could be accomplished by the use of hydraulic model tests, as experiments have shown that C differs only slightly with the scale of the model.

Many structures built in recent years have had hydraulic model tests and coefficients of discharge computed. In many cases it may be possible to adjust the coefficients of the model for use on the prototype.

Then, again, it may be possible on many overflow dams to determine the discharge by one of the methods described elsewhere in this volume as for example, the current meter method or the pitot tube method. These methods may be used to calibrate the crest of the dam for various heads.

67. Calibration of gates and sluices. It may be desirable and necessary in many irrigation water distribution works to measure the flow of water through gates and sluices as a means of determining all or a part of the total flow. This necessitates the calibration of the gates or sluices.

In the calibration of an individual gate unit, the discharge may be measured by one of the standard methods described elsewhere in this volume. A series of discharge measurements covering the range of openings is made and the mean operating head is recorded for each measurement. After the heads, as measured for each discharge measurement, are adjusted to a common head and the corresponding discharge computed, the discharge curve may be plotted showing the opening as the ordinate and the discharge for the common head as the abscissa. For conveninece in operating the units, a rating table may be computed providing the discharge in second-feet for each opening for a series of operating heads.

In the calibration of sluices, sometimes called rating sections, the current meter method is commonly used. It may be practicable to calibrate the section by use of a temporary weir upstream from the section, provided there is sufficient fall. The calibration tests consist of measuring the discharge for various depths of flow in the sluice or rating section and plotting the discharges against depths. The channel should be of regular section and free from disturbance of flow by upstream conditions such

114

as bends, multiple gates operating in unbalanced openings, waves, and other distorting influences.

68. Measuring control for canals. Irrigation water canal systems include frequent drops to adjust the canal grades to the topography of the land which it serves. For any given quantity of flow, canal shape, slope, and roughness, a certain depth of flow will be just right to main uniform flow -- in which the water surface is parallel to the bottom of the canal. To maintain such conditions for a canal upstream from a drop, the Bureau has adopted a device known as the measuring control. It consists of a short constricted section of channel in which the draw down of the water surface occurs as it conducts the flow from the canal to a chute or other drop structure. The measuring control is designed in dimensions and proportions to provide that the depth in the canal upstream a short distance, would be very nearly normal for any discharge, or in other words, it is designed to maintain the same flow conditions in the canal as would occur if the drop did not exist.

Actually the measuring control is designed to maintain normal canal depth at a relatively high discharge and at a relatively low discharge. It is generally found that the depths maintained in the canal are nearly normal for intermediate discharges.

A gage set in the canal a short distance upstream from the control section may be used as the gage of the canal at this station. A rating table may be made for the gage from discharge determinations made from current meter measurements of the canal for various depths.

69. Determination of flow by adjustments for gain or loss in storage. When the capacity, gain or loss in storage, and the inflow to a reservoir are known, the discharge from the reservoir may be computed. Likewise when the capacity, gain or loss in storage and the discharge from the reservoir are known, the inflow may be computed.

In each of these computations the gain or loss in storage in a given period of time may be taken from the capacity table, which

115

gives reservoir capacity usually in acre-feet for various gage heights of water. The change in reservoir capacity in acre-feet converted to second-feet for the period of time over which the change occurred increased by the inflow or decreased by the discharge will give the average discharge or inflow, respectively, for the reservoir.

Adjustments for evaporation and wind effect on gage readings may be necessary in reservoirs of large area.

70. Clausen-Pierce weir gage. A device now used in some irrigation regions is the Calusen-Pierce weir gage. It may be used for measurement of discharges ranging from less than 1 second-foot to several thousand. It is designed to measure the discharge over rectangular suppressed weirs, the gage indicating the discharge per unit length of weir. The designers have aimed to simplify the general requirements for the proper setting and operation of weirs, as regards the velocity of approach and submergence. The other general requirements for weir settings hold for the use of this method of measurement.

This device consists of a graduated extensible rod equipped with a piezometer on the back. Measurements are made with the rod held vertically on the crest of the weir. The rod is so designed and calibrated as to include the effect of velocity of approach for free-flowing weirs. The discharge over submerged weirs is observed with the use of the extension feature and the piezometer in two operations.

It has been found that the gage is generally more accurate for free-flowing weirs than for submerged weirs.

71. Commercial meters. It is frequently necessary and desirable to maintain records of volume of water delivered to irrigators rather than merely the rate of flow over a period of time. For relatively small quantities of water, mechanical meters recording the volume of water passing, may be used. It should be noted that many of the flow meters indicating momentary rate of flow may be equipped with auxiliary apparatus to record the volumetric flow, and volumetric

116

meters may be equipped with auxiliary devices for indicating the rate of momentary flow.

Commercial meters are generally classified as of the displacement type, the velocity type and the by-pass type.

For open channels there are several commercial meters of the velocity-type among which are the Hill, Grant-Mitchell, and the Reliance meters. In addition, the Dethridge meter originally developed in Australia has been used to a limited extent in this country.

Commercial meters have the advantage of obviating the necessity of computing the total volume of discharge where the water is sold on the volume basis. These meters should be inspected and attended to regularly and frequently as detritus suspended in the water sometimes interfers with their continuous operation. Also each meter should be calibrated in place and periodically, according to the need, as corrosion may produce friction in moving parts and effect the calibration. Probably the greatest limitation in the use of all types of commercial meters is their relatively high cost.

CHAPTER VII

72. Rate meters: Venturi meter, flow-nozzle, and orifice meter. For the measurement of flow in conduits under pressure three devices are commonly used: the Venturi meter, the flow nozzle, and the thin-plate orifice, the computation of flow through each being based on the same formula, which is:

$$Q = \frac{C A_2 \sqrt{2gh}}{\sqrt{1 - r^4}} \qquad (38)$$

where A_2 = cross-sectional area of the throat, in square feet

h = difference in pressure head between upstream pressure measuring section and the downstream pressure measuring section, in feet

g = 32.2 feet per second per second

r = the ratio of the throat diameter to pipe diameter = $\frac{D_2}{D_1}$, and

C = the coefficient of discharge

These metering devices are illustrated in diagrammatic form in figures 25, 26, and 27.

The coefficient of discharge for the Venturi meter will vary from the approximate value of 0.935 for small throat velocities and diameters to 0.988 for relatively large throat velocities and diameters.

The coefficient of discharge for the flow nozzle will vary from 1.0 to 0.97 or lower. Inasmuch as the flow conditions at the entrance to the throat are similar to those of the Venturi meter, the coefficients should be nearly the same with the same diameter ratio r.

The coefficients of discharge for the orifice meter will vary from approximately 0.600 for a value of r of 0.20 to 0.715 for an r of 0.71.

73. The Venturi meter. This measuring device has been

118

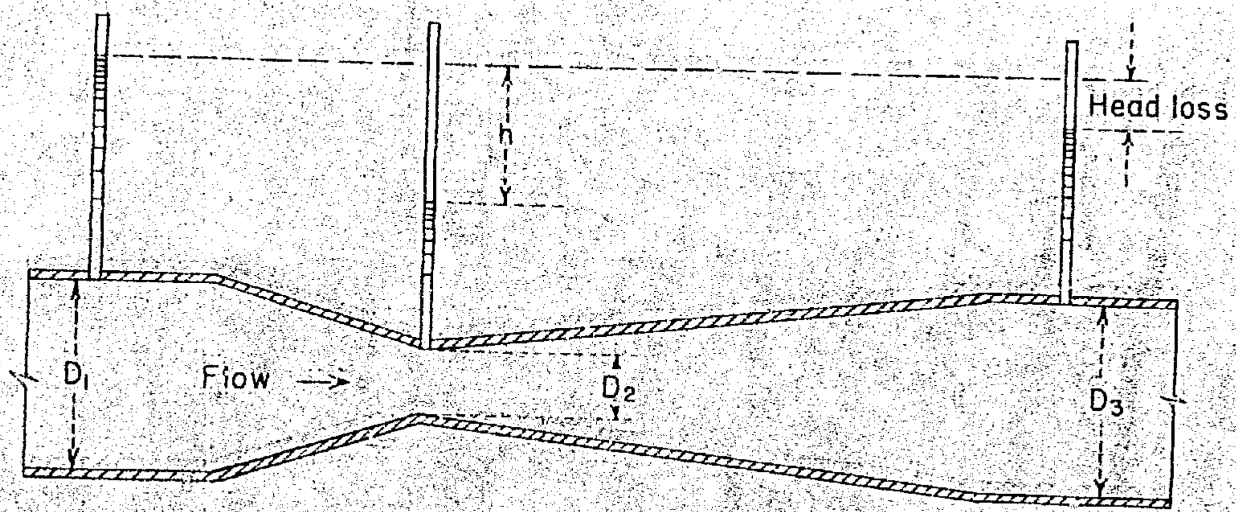


Figure 25. - Diagram of Venturi meter

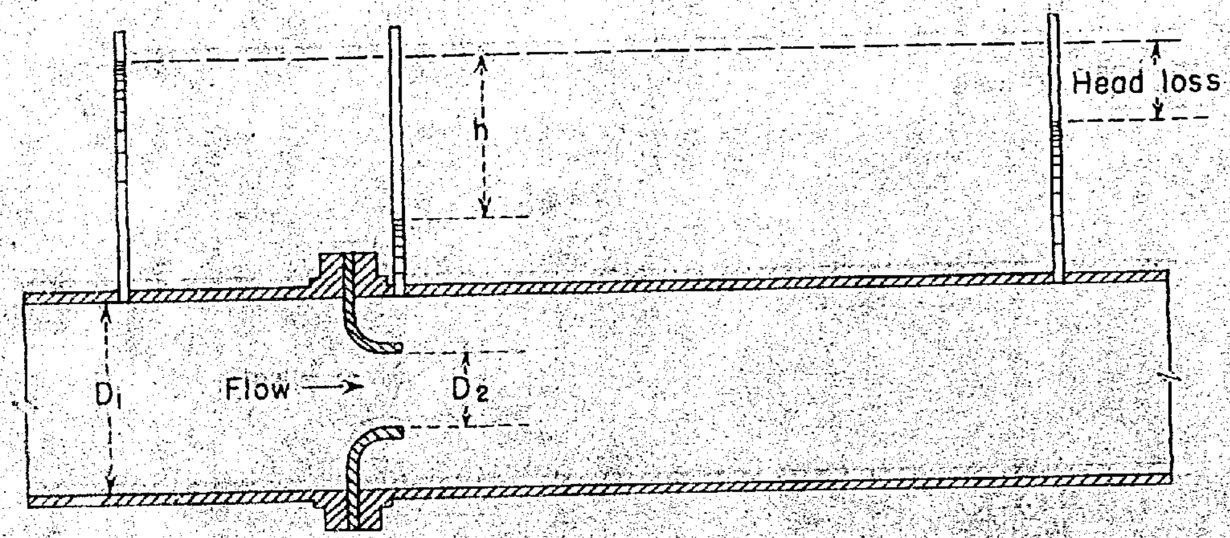


Figure 26. - Diagram of flow nozzle

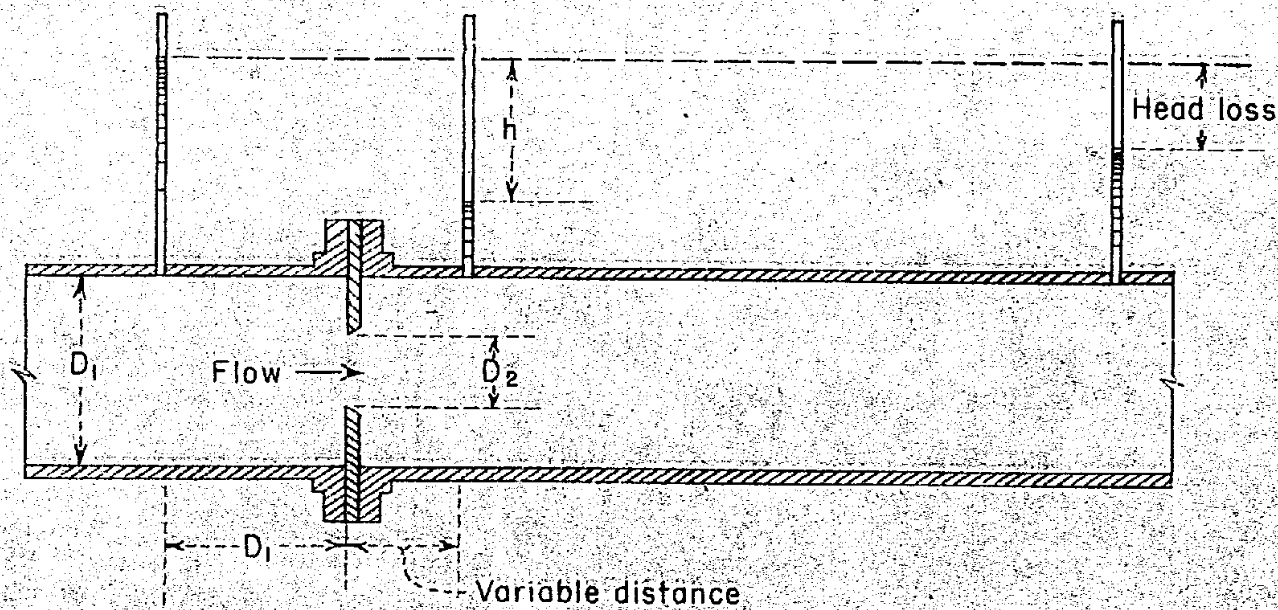


Figure 27. - Diagram of orifice-meter

generally considered too costly for irrigation water distribution systems except in the larger diversion structures. In some instances, the sizes and proportions of the meter have not been suitable for irrigation structures. In spite of its limitations the meter is desirable as an irrigation water measuring device for several reasons. It is more accurate than most other devices which could be used in its place. It may be adapted either to open channels or pipe lines and has been applied to delivery of small laterals in turnout structures. There are no moving parts and little attention is required. Table or diagrams giving the flow for various heads may be prepared and flow indicators, either recording or non-recording, are often used.

Commercial meters of brass or bronze are available for common pipe sizes up to about two inches in diameter. Larger meters are usually of cast iron, the throat normally being lined with bronze. Still larger Venturi meters have been constructed of concrete, the upstream end and the throat being of finished metal.

The Venturi meter of large size has not been standardized for general irrigation practice to the extent that sizes, shapes, and coefficients are well known for meters individually constructed of such materials as concrete or wood.

74. Flow-nozzles. The principle underlying the use of the flow-nozzle is the same as for the Venturi meter, equation (38) applying. In effect, the flow-nozzle is a Venturi meter that has been simplified and shortened by omitting the long diffuser on the outlet side.

The upstream pressure connection is frequently made through a hole in the wall of the conduit at a distance of about one pipe-diameter upstream from the starting point of the flare of the nozzle. In this manner the pressure observed is that of the stream before it has begun to turn inward due to the inlet flare of the nozzle. The downstream pressure connection may be made through the pipe wall opposite the straight portion of the nozzle throat.

The shape of the nozzle provides for the flow of water through the throat section in a straight cylindrical jet without contraction so that the coefficient is almost the same as for the Venturi meter. In the flow-nozzle the jet is allowed to expand of its own accord, causing a greater loss of head than in the Venturi meter where the flow is allowed to expand gradually.

Flow-nozzles have been used little for the measurement irrigation water probably for the reason that there is a lack of standardization in design data.

75. Orifice meter. In the early days of irrigation the sharp edged orifice was used for the measurement of water in open channels where sufficient head was available. A thin-plate orifice inserted across a pipe line can be used for the measurement of flow in the same manner as the Venturi meter, the same formula (38), applying.

As shown in figure 27, the upstream pressure connection is located at a distance of about one pipe diameter upstream from the orifice plate. The location of the downstream connection is more important. The pressure of the jet varies from a minimum at the vena contracta, (the smallest cross-section of the jet), to a maximum at about four to five diameters downstream from the orifice plate. The pressure is usually taken at the vena contracta in order that a larger pressure difference across the orifice may be obtained. The location of the vena contracta may be located from data provided in standard hydraulic handbooks.

For this setting the coefficient of discharge ranges from 0.600 for a value of r of 0.20 to 0.628 for an r of 0.50. Therefore, because of its nearly constant coefficient of discharge the device is desirable. Its principal disadvantage as compared to the Venturi meter is its greater loss of head.

76. Pitot tube method. The flow in pipe lines under pressure may be computed from velocity and area observations made with the use of a pitot tube or a commercial adaption thereof. This device and the procedure for its use is described briefly in section 61.

The details of the design of and use of the pitot tube are covered fully in the American Society of Mechanical Engineers publication, "Fluid Meters, Their Theory and Application."

77. The salt-velocity method. The flow in closed conduits under pressure may be computed from velocity and area observations made with the use of the salt-velocity method. This method is described in section 68 for use in closed conduits as well as open channels.

78. Color-Velocity method. This method of measuring discharge of pipe lines consists of determining the velocity of a slug of dye between two stations in the line. This velocity, used as the mean velocity of flow, multiplied by the cross-sectional area of the pipe flow gives the discharge.

Fluorescein, potassium permanganate or other coloring matter may be used. Fluorescein, a red powder, produces a greenish color when dissolved in slightly alkaline water. This distinctive color is easily visible in very dilute solutions.

The procedure ordinarily used in making the velocity measurements is as follows: a small slug of the dye is injected into the pipe line flow at the upstream station by means of a high pressure pump or "color gun." Time observations are made at the instant the dye is injected and at its first and last appearance at the downstream station, usually at the outlet. The mean velocity is computed from the mean time required for the slug of dye to traverse the course, and the length of the course. A discussion of this method appears in U. S. Department of Agriculture Bulletin 376. This method is applicable to fairly long pipe lines. From the few tests in which this method has been used it appears to be very accurate, if the reach of test is comparatively long. However, the accuracy of measurement would be increased if means were available for recording the passage of the color.

79. California Pipe Method of Water Measurement. E. E. Van Leer developed a method for measuring the discharge from the open end of

a partially filled horizontal pipe discharging freely into the air. It can also be adapted to the measurement of discharge in small open channels where such flow can be diverted through a horizontal pipe flowing partially full and discharging freely into the air.

Four important specifications are necessary for accurate discharge determinations: the discharge pipe must be level, it must discharge partially full, it must discharge freely into air and the velocity of approach must be at a minimum.

Figure 28 illustrates one method of achieving these minimum essentials. Other plans may be possible. With such an arrangement the only measurements necessary are of the inside diameter of the pipe, and of the vertical distance from the upper inside surface of the pipe to the surface of the flowing water at the end of the pipe. With this information the discharge may be computed by the formula:

$$Q = 8.69 \left(1 - \frac{a}{d}\right)^{1.88} d^{2.48}$$

where Q = discharge in second-feet

a = distance, in feet, measured in the plane of the end of the pipe from the top of the inside surface of the pipe to the water surface, and

d = internal diameter of the pipe in feet.

This formula derived from experimental data for pipes 3 to 10 inches in diameter gives accurate values for discharge for this range of sizes. Tables 35 and 36 are provided to assist in computing discharges by this method.

An illustration of the computation of discharge by this method follows: Suppose it is found that a clean, new, 8-inch pipe (inside diameter = 8.071 inches) is discharging under conditions specified in this section and it is found that the vertical distance from the top of the inside surface of the pipe to the water surface at the end of the pipe is 3½". Converting these measurements in inches to their equivalents in feet:

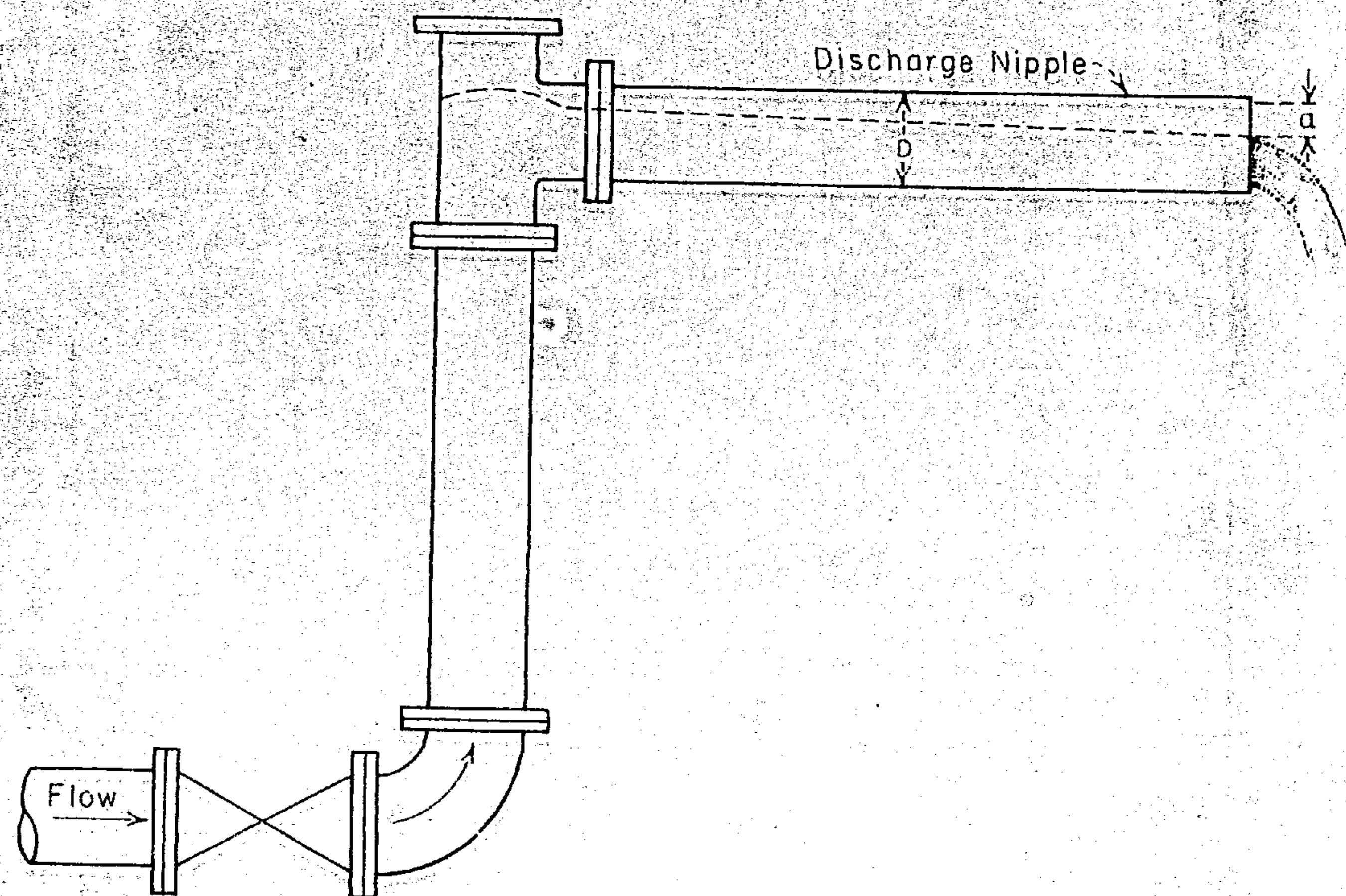


Figure 26. - A typical arrangement for measuring flow by the California pipe method

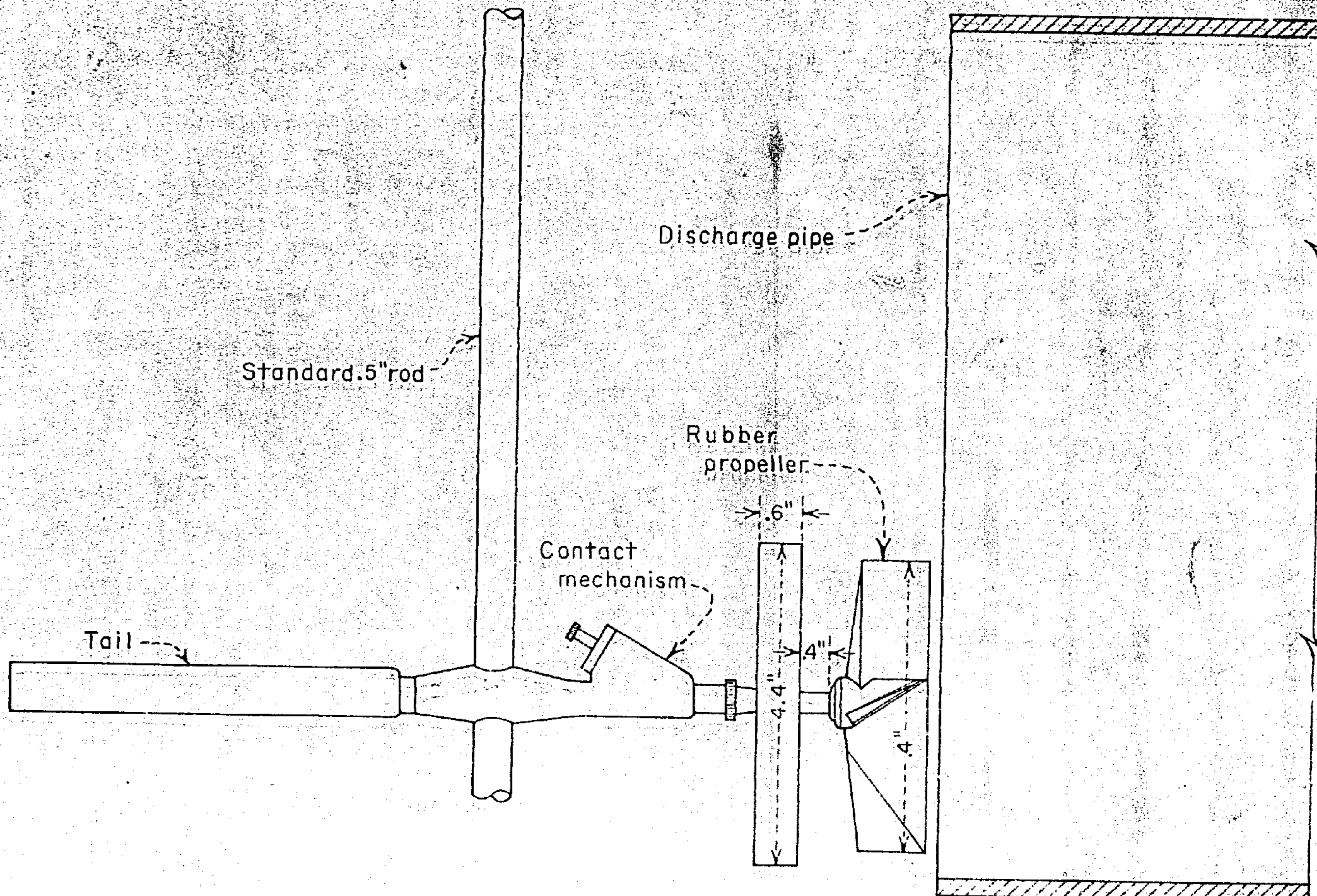


Figure 29. - Hoff meter equipped for discharge measurement of pipe flowing full and discharging into air.

Table 35. Values of $8.69 \left(1-\frac{a}{d}\right)^{1.88}$ for computation of discharges by the California pipe method.

$\frac{a}{d}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	8.69	8.53	8.37	8.21	8.05	7.89	7.74	7.58	7.43	7.28
.1	7.13	6.98	6.83	6.69	6.54	6.40	6.26	6.12	5.98	5.85
.2	5.71	5.58	5.45	5.32	5.19	5.06	4.93	4.81	4.68	4.56
.3	4.44	4.33	4.21	4.09	3.98	3.87	3.76	3.65	3.54	3.43
.4	3.33	3.22	3.12	3.02	2.92	2.82	2.73	2.63	2.54	2.45
.5	2.361	2.273	2.186	2.102	2.018	1.937	1.857	1.778	1.701	1.626
.6	1.552	1.480	1.409	1.340	1.273	1.207	1.143	1.081	1.020	.961
.7	.904	.848	.794	.741	.690	.641	.594	.548	.504	.462
.8	.422	.383	.346	.311	.277	.246	.216	.189	.161	.137
.9	.1146	.0940	.0753	.0586	.0438	.0311	.0205	.0119	.0056	.0015

$$d = \frac{8.071}{12} = 0.672 \text{ feet, and}$$

$$a = \frac{3.5}{12} = 0.292 \text{ feet.}$$

Therefore, $\frac{a}{d} = \frac{0.292}{0.673} = 0.433.$

From table 35 the value of $8.69(1 - \frac{a}{d})^{1.88}$ for a value of $\frac{a}{d} = 0.433$ is 2.99. From table 36, $d^{2.48}$ is found to be 0.374.

Therefore, the discharge is 2.99 x 0.374 or 1.12 second-feet.

80. Current meter method. A method of measurement of flow of irrigation water from pipes flowing full, usually from pumps, with the use of a propeller type current meter has recently been developed at the Colorado Agricultural Experiment Station.

The equipment needed for the discharge determinations is a propeller type Ott or Hoff type meter with rubber propellers, equipped with a guard ring for protection of the meter and for steadying it when being used, illustrated in figure 29.

The velocity of the jet is determined by the combination horizontal, vertical, and circular integration method in which the meter is passed uniformly across the horizontal diameter, vertical diameter and around the outer annular area of the pipe.

With the velocity observed in this method of measurement the discharge may be computed with the following formula:

$$Q = (419A - 5)V$$

in which Q = discharge in gallons per minute

A = the area of the pipe in square feet, and

V = velocity measured in feet per second as indicated by the meter.

The discharge pipe should be horizontal and at least six feet long. Measurements of spiral flow with the current meter are not satisfactory. It is necessary that the pipe be flowing full.

81. Calibration of water wheels, pumps, and valves. It may

Table 36. 2.48 powers of numbers for computation of discharges by the California pipe method.

Number	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	......	......	......	.0002	.0003	.0006	.0009	.0014	.0019	.0025
.1	.0033	.0042	.0052	.0064	.0076	.0090	.0106	.0123	.0142	.0163
.2	.0185	.0209	.0234	.0261	.0290	.0321	.0354	.0389	.0426	.0464
.3	.0505	.0548	.0593	.0640	.0689	.0740	.0794	.0849	.0907	.0968
.4	.1031	.1096	.1163	.1233	.1309	.1380	.1458	.1537	.1620	.1705
.5	.179	.188	.198	.207	.217	.227	.237	.248	.259	.270
.6	.282	.294	.306	.318	.331	.344	.357	.370	.384	.398
.7	.413	.428	.443	.458	.474	.490	.506	.523	.540	.557
.8	.575	.593	.611	.630	.649	.668	.688	.708	.728	.749
.9	.770	.791	.813	.835	.858	.881	.904	.927	.951	.975
1.0	1.000	1.025	1.050	1.076	1.102	1.129	1.155	1.183	1.210	1.238
1.1	1.267	1.295	1.324	1.354	1.384	1.414	1.445	1.476	1.508	1.539
1.2	1.572	1.604	1.637	1.671	1.705	1.739	1.774	1.809	1.845	1.881
1.3	1.917	1.954	1.991	2.028	2.066	2.105	2.144	2.183	2.223	2.263
1.4	2.304	2.345	2.386	2.428	2.470	2.513	2.556	2.600	2.644	2.689
1.5	2.73	2.78	2.82	2.87	2.92	2.96	3.01	3.06	3.11	3.16
1.6	3.21	3.26	3.31	3.36	3.41	3.46	3.51	3.57	3.62	3.67
1.7	3.73	3.78	3.84	3.89	3.95	4.01	4.06	4.12	4.18	4.24
1.8	4.30	4.36	4.42	4.48	4.54	4.60	4.66	4.72	4.79	4.85
1.9	4.91	4.98	5.04	5.11	5.17	5.24	5.31	5.37	5.44	5.51
2.0	5.58	5.65	5.72	5.79	5.86	5.93	6.00	6.08	6.15	6.22
2.1	6.30	6.37	6.45	6.52	6.60	6.67	6.75	6.83	6.91	6.99
2.2	7.07	7.15	7.23	7.31	7.39	7.47	7.55	7.64	7.72	7.81
2.3	7.89	7.98	8.06	8.15	8.24	8.32	8.41	8.50	8.59	8.68
2.4	8.77	8.86	8.95	9.05	9.14	9.23	9.32	9.42	9.51	9.61
2.5	9.70	9.80	9.90	9.99	10.09	10.19	10.29	10.39	10.49	10.59
2.6	10.69	10.80	10.90	11.00	11.11	11.21	11.32	11.42	11.53	11.64
2.7	11.74	11.85	11.96	12.07	12.18	12.29	12.40	12.51	12.62	12.74
2.8	12.85	12.97	13.08	13.19	13.31	13.43	13.55	13.67	13.78	13.90
2.9	14.02	14.14	14.26	14.38	14.50	14.63	14.75	14.87	15.00	15.12
3.0	15.25									

be desirable and necessary in some irrigation water distribution works to measure the flow all or in part, through water wheels and valves. For such a case calibration of these appurtenances is necessary either at the site using one of the approved methods of measuring discharge or by an analysis of observations on hydraulic models in the laboratory. Both methods have been used with success.

In calibration of turbines, pumps and outlet valves the following variable conditions must be considered: The type of period during which each unit is in operation, the percent of opening of each unit, and the head and tailwater elevations for the period of operation of the unit.

In the calibration of an individual pump or outlet valve unit a series of discharge measurements covering the range of valve openings and the mean operating head is recorded for each measurement. After the heads, as measured for each discharge measurement, are adjusted to a common head and the corresponding discharge computed, the discharge curve may be plotted showing opening as the ordinate and the discharge for the common head as the abscissa. For convenience in operating the valves, for example, a rating table may be computed providing the discharge in second feet for each opening, in percentage of fully open, for a series of operating heads.

In the calibration of water turbine units, a discharge-power output relationship is generally desirable and convenient. This may be done by determining the average output of each unit during the period of the discharge measurement for various effective constant heads, the units running at or near constant load.

52. <u>Commercial meters</u>. Commercial meters for closed conduits are generally classified as to the type of operation; that is, the displacement type, the velocity type or the by-pass type. These meters record the volume passing, making it unnecessary to compute total volume from flow records observed on flow meters. Many flow meters, however, may be equipped with auxiliary apparatus to record the instantaneous flow.

These meters have the advantage of obviating the necessity of computing the total volume of discharge where water is sold on the volume basis. Water measured in closed conduits with mechanical meters must be free of foreign matter. Meters should be inspected regularly to detect abnormal wear, corrosion or any other change that would tend to alter the meter's accuracy.

A flow meter employing the variable-area feature is used occasionally for measurement of small flow. This type of meter is seldom used for large quantities as it is likely to impose a large head loss. In this meter the flow rises through a conical shaped passage, the cross-sectional area increasing with the height. The rate of flow is measured by the height of a disc which the flow sustains in the vertical conical tube. In one meter the conical tube is transparent and the position of the disc may be observed directly against the graduations marked on the tube.

The greatest limitation of the many commercial volumetric meters and adaptations of flow meters is their relatively high cost.

83. The Gibson Method. This method was developed for measuring the discharge of valves, turbines or regulating devices at the end of a pipe or penstock. The closed pressure conduit should be at least 25 feet in length, preferably longer. The method may be applied to conduits of non-uniform diameter by dividing the length into sections of assumed uniform diameter.

The discharge is computed from pressure measurements taken over the period of time over which the valve or regulating device is gradually closed, the cross-sectional area of the conduit, and its length. The variation of pressure is automatically recorded with respect to time on apparatus especially devised for this method. The method requires the special equipment developed for it and personnel specially trained for its use. It is described in detail in volume 86, Transactions, American Society of Mechanical Engineers, 1923.

PART IV - TABLES

84. Tables for computation of discharge of various water measuring devices and tables of equivalents. The following tables have been extracted from the text portion of this manual for convenience in ordinary computations:

Table No.	Title
1	Acre-feet equivalent to a given number of second-feet flowing for a given length of time.
3	Three-halves powers of numbers.
4	Discharge of standard contracted rectangular weirs in second-feet.
5	Discharge of standard suppressed rectangular weirs in second-feet.
6	Discharge of standard Cipolletti weirs in second-feet
8	Coefficients to be applied to discharge taken from tables 4, 5 and 6 for a head H, to obtain the discharge of the same weir when a velocity of approach V, exists.
9	Coefficients to be applied to a discharge given by tables 4, 5 and 6 from a head, H, to give discharge of same weir submerged.
11	Free-flow discharges in second-feet per foot of width of farmers' short box measuring flumes.
15	Free-flow discharge through 3-inch Parshall flumes.
16	Free-flow discharge through 6-inch Parshall flumes.
17	Free-flow discharge through 9-inch Parshall flumes.
18	Free-flow discharge through 1-foot to 8-foot Parshall flumes

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time.

Second-feet	Minutes			Hours					
	15	30	45	1	2	3	4	5	6
0.01	0.00021	0.00041	0.00062	0.00083	0.00165	0.00248	0.00331	0.00413	0.00496
.02	.00041	.00083	.00124	.00165	.00331	.00496	.00661	.00826	.00992
.03	.00062	.00124	.00186	.00248	.00496	.00744	.00992	.01240	.01488
.04	.00083	.00165	.00248	.00331	.00661	.00992	.01322	.01653	.01983
.05	.00103	.00207	.00310	.00413	.00826	.01240	.01653	.02066	.02479
.06	.00124	.00248	.00372	.00496	.00992	.01488	.01983	.02479	.02975
.07	.00145	.00289	.00434	.00579	.01157	.01735	.02314	.02893	.03471
.08	.00165	.00331	.00496	.00661	.01322	.01983	.02645	.03306	.03967
.09	.00186	.00372	.00558	.00744	.01488	.02231	.02975	.03719	.04463
.10	.00207	.00413	.00620	.00826	.01653	.02479	.03306	.04132	.04959
.11	.00227	.00455	.00682	.00909	.01818	.02727	.03636	.04545	.05455
.12	.00248	.00496	.00744	.00992	.01983	.02975	.03967	.04959	.05950
.13	.00269	.00537	.00806	.01074	.02149	.03223	.04297	.05372	.06446
.14	.00289	.00579	.00868	.01157	.02314	.03471	.04628	.05785	.06942
.15	.00310	.00620	.00930	.01240	.02479	.03719	.04959	.06198	.07438
.16	.00331	.00661	.00992	.01322	.02645	.03967	.05289	.06611	.07934
.17	.00351	.00702	.01054	.01405	.02810	.04215	.05620	.07025	.08430
.18	.00372	.00744	.01116	.01488	.02975	.04463	.05950	.07438	.08926
.19	.00393	.00785	.01178	.01570	.03140	.04711	.06281	.07851	.09421
.20	.00413	.00826	.01240	.01653	.03306	.04959	.06611	.08264	.09917
.21	.00434	.00868	.01302	.01735	.03471	.05207	.06942	.08678	.10413
.22	.00455	.00909	.01364	.01818	.03636	.05455	.07273	.09091	.10909
.23	.00475	.00950	.01426	.01901	.03802	.05702	.07603	.09504	.11405
.24	.00496	.00992	.01488	.01983	.03967	.05950	.07934	.09917	.11901
.25	.00517	.01033	.01550	.02066	.04132	.06198	.08264	.10331	.12397
.26	.00537	.01074	.01611	.02149	.04297	.06446	.08595	.10744	.12893
.27	.00558	.01116	.01673	.02231	.04463	.06694	.08926	.11157	.13388
.28	.00579	.01157	.01735	.02314	.04628	.06942	.09256	.11570	.13884
.29	.00599	.01198	.01797	.02397	.04793	.07190	.09587	.11983	.14380
.30	.00620	.01240	.01859	.02479	.04959	.07438	.09917	.12397	.14876
.31	.00640	.01281	.01921	.02562	.05124	.07686	.10248	.12810	.15372
.32	.00661	.01322	.01983	.02645	.05289	.07934	.10579	.13223	.15868
.33	.00682	.01364	.02045	.02727	.05455	.08182	.10909	.13636	.16364
.34	.00702	.01405	.02107	.02810	.05620	.08430	.11240	.14049	.16859
.35	.00723	.01446	.02169	.02893	.05785	.08678	.11570	.14463	.17355
.36	.00744	.01488	.02231	.02975	.05950	.08926	.11901	.14876	.17851
.37	.00764	.01529	.02293	.03058	.06116	.09173	.12231	.15289	.18347
.38	.00785	.01570	.02355	.03140	.06281	.09421	.12562	.15702	.18843
.39	.00806	.01611	.02417	.03223	.06446	.09669	.12893	.16116	.19339
.40	.00826	.01653	.02479	.03306	.06611	.09917	.13223	.16529	.19835
.41	.00847	.01694	.02541	.03388	.06777	.10165	.13554	.16942	.20331
.42	.00868	.01735	.02603	.03471	.06942	.10413	.13884	.17355	.20826
.43	.00888	.01777	.02665	.03554	.07107	.10661	.14215	.17769	.21322
.44	.00909	.01818	.02727	.03636	.07273	.10909	.14545	.18182	.21818
.45	.00930	.01859	.02789	.03719	.07438	.11157	.14876	.18595	.22314
.46	.00950	.01901	.02851	.03802	.07603	.11405	.15207	.19008	.22810
.47	.00971	.01942	.02913	.03884	.07769	.11653	.15537	.19421	.23306
.48	.00992	.01983	.02975	.03967	.07934	.11901	.15868	.19835	.23802
.49	.01012	.02025	.03037	.04049	.08099	.12149	.16198	.20248	.24297
.50	.01033	.02066	.03099	.04132	.08264	.12397	.16529	.20661	.24795

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second-feet	Minute			Hours					
	15	30	45	1	2	3	4	5	6
0.51	0.01054	0.02107	0.03161	0.04215	0.08430	0.12645	0.16859	0.21074	0.25289
.52	.01074	.02149	.03223	.04297	.08595	.12893	.17190	.21488	.25785
.53	.01095	.02190	.03285	.04380	.08760	.13140	.17521	.21901	.26281
.54	.01116	.02231	.03347	.04463	.08926	.13388	.17851	.22314	.26777
.55	.01136	.02273	.03409	.04545	.09091	.13636	.18182	.22727	.27273
.56	.01157	.02314	.03471	.04628	.09256	.13884	.18512	.23140	.27769
.57	.01178	.02355	.03533	.04711	.09421	.14132	.18843	.23554	.28264
.58	.01198	.02397	.03595	.04793	.09587	.14380	.19173	.23967	.28760
.59	.01219	.02438	.03657	.04876	.09752	.14628	.19504	.24380	.29256
.60	.01240	.02479	.03719	.04959	.09917	.14876	.19835	.24793	.29752
.61	.01260	.02521	.03781	.05041	.10083	.15124	.20165	.25207	.30248
.62	.01281	.02562	.03843	.05124	.10248	.15372	.20496	.25620	.30744
.63	.01302	.02603	.03905	.05207	.10413	.15620	.20826	.26033	.31240
.64	.01322	.02645	.03967	.05289	.10579	.15868	.21157	.26446	.31735
.65	.01343	.02686	.04029	.05372	.10744	.16116	.21488	.26859	.32231
.66	.01364	.02727	.04091	.05455	.10909	.16364	.21818	.27273	.32727
.67	.01384	.02769	.04153	.05537	.11074	.16611	.22149	.27686	.33223
.68	.01405	.02810	.04215	.05620	.11240	.16859	.22479	.28099	.33719
.69	.01426	.02851	.04277	.05702	.11405	.17107	.22810	.28512	.34215
.70	.01446	.02893	.04339	.05785	.11570	.17355	.23140	.28926	.34711
.71	.01467	.02934	.04401	.05868	.11735	.17603	.23471	.29339	.35207
.72	.01488	.02975	.04463	.05950	.11901	.17851	.23802	.29752	.35702
.73	.01508	.03017	.04525	.06033	.12066	.18099	.24132	.30165	.36198
.74	.01529	.03058	.04587	.06116	.12231	.18347	.24463	.30579	.36694
.75	.01550	.03099	.04649	.06198	.12397	.18595	.24793	.30992	.37190
.76	.01570	.03140	.04711	.06281	.12562	.18843	.25124	.31405	.37686
.77	.01591	.03182	.04773	.06364	.12727	.19091	.25455	.31818	.38182
.78	.01611	.03223	.04835	.06446	.12893	.19339	.25785	.32231	.38678
.79	.01632	.03264	.04897	.06529	.13058	.19587	.26116	.32645	.39173
.80	.01653	.03306	.04959	.06611	.13223	.19835	.26446	.33058	.39669
.81	.01673	.03347	.05021	.06694	.13388	.20083	.26777	.33471	.40165
.82	.01694	.03388	.05083	.06777	.13554	.20331	.27107	.33884	.40661
.83	.01715	.03430	.05145	.06859	.13719	.20579	.27438	.34297	.41157
.84	.01735	.03471	.05207	.06942	.13884	.20826	.27769	.34711	.41653
.85	.01756	.03512	.05269	.07025	.14050	.21074	.28099	.35124	.42149
.86	.01777	.03554	.05331	.07107	.14215	.21322	.28430	.35537	.42645
.87	.01797	.03595	.05393	.07190	.14380	.21570	.28760	.35950	.43140
.88	.01818	.03636	.05455	.07273	.14545	.21818	.29091	.36364	.43636
.89	.01839	.03678	.05517	.07355	.14711	.22066	.29421	.36777	.44132
.90	.01860	.03719	.05579	.07438	.14876	.22314	.29752	.37190	.44628
.91	.01880	.03760	.05640	.07521	.15041	.22562	.30083	.37603	.45124
.92	.01901	.03802	.05702	.07603	.15207	.22810	.30413	.38017	.45620
.93	.01921	.03843	.05764	.07686	.15372	.23058	.30744	.38430	.46116
.94	.01942	.03884	.05826	.07769	.15537	.23306	.31074	.38843	.46611
.95	.01963	.03926	.05888	.07851	.15702	.23554	.31405	.39256	.47107
.96	.01983	.03967	.05950	.07934	.15868	.23802	.31735	.39669	.47603
.97	.02004	.04008	.06012	.08017	.16033	.24050	.32066	.40083	.48099
.98	.02025	.04049	.06074	.08099	.16198	.24297	.32397	.40496	.48595
.99	.02045	.04091	.06136	.08182	.16364	.24545	.32727	.40909	.49091
1.00	.02066	.04132	.06198	.08264	.16529	.24793	.33058	.41322	.49587

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second-feet	Hours								
	7	8	9	10	11	12	13	14	15
0.01	0.00579	0.00661	0.00744	0.00826	0.00909	0.00992	0.01074	0.01157	0.01240
.02	.01157	.01322	.01488	.01653	.01818	.01983	.02149	.02314	.02479
.03	.01735	.01983	.02231	.02479	.02727	.02975	.03223	.03471	.03719
.04	.02314	.02645	.02975	.03306	.03636	.03967	.04297	.04628	.04959
.05	.02893	.03306	.03719	.04132	.04545	.04959	.05372	.05785	.06198
.06	.03471	.03967	.04463	.04959	.05455	.05950	.06446	.06942	.07438
.07	.04049	.04628	.05207	.05785	.06364	.06942	.07521	.08099	.08678
.08	.04628	.05289	.05950	.06611	.07273	.07934	.08595	.09256	.09917
.09	.05207	.05950	.06694	.07438	.08182	.08926	.09669	.10413	.11157
.10	.05785	.06611	.07438	.08264	.09091	.09917	.10744	.11570	.12397
.11	.06364	.07273	.08182	.09091	.10000	.10909	.11818	.12727	.13636
.12	.06942	.07934	.08926	.09917	.10909	.11901	.12893	.13884	.14876
.13	.07521	.08595	.09669	.10744	.11818	.12893	.13967	.15041	.16116
.14	.08099	.09256	.10413	.11570	.12727	.13884	.15041	.16198	.17355
.15	.08678	.09917	.11157	.12397	.13636	.14876	.16116	.17355	.18595
.16	.09256	.10579	.11901	.13223	.14545	.15868	.17190	.18512	.19835
.17	.09835	.11240	.12645	.14049	.15455	.16859	.18264	.19669	.21074
.18	.10413	.11901	.13388	.14876	.16364	.17851	.19339	.20826	.22314
.19	.10992	.12562	.14132	.15702	.17273	.18843	.20413	.21983	.23554
.20	.11570	.13223	.14876	.16529	.18182	.19835	.21488	.23140	.24793
.21	.12149	.13884	.15620	.17355	.19091	.20826	.22562	.24297	.26033
.22	.12727	.14545	.16364	.18182	.20000	.21818	.23636	.25455	.27273
.23	.13306	.15207	.17107	.19008	.20909	.22810	.24711	.26611	.28512
.24	.13884	.15868	.17851	.19835	.21818	.23802	.25785	.27769	.29752
.25	.14463	.16529	.18595	.20661	.22727	.24793	.26859	.28926	.30992
.26	.15041	.17190	.19339	.21488	.23636	.25785	.27934	.30083	.32231
.27	.15620	.17851	.20083	.22314	.24545	.26777	.29008	.31240	.33471
.28	.16198	.18512	.20826	.23140	.25455	.27769	.30083	.32397	.34711
.29	.16777	.19173	.21570	.23967	.26364	.28760	.31157	.33554	.35950
.30	.17355	.19835	.22314	.24793	.27273	.29752	.32231	.34711	.37190
.31	.17934	.20496	.23058	.25620	.28182	.30744	.33306	.35868	.38430
.32	.18512	.21157	.23802	.26446	.29091	.31735	.34380	.37025	.39669
.33	.19091	.21818	.24545	.27273	.30000	.32727	.35455	.38182	.40909
.34	.19669	.22479	.25289	.28099	.30909	.33719	.36529	.39339	.42149
.35	.20248	.23140	.26033	.28926	.31818	.34711	.37603	.40496	.43388
.36	.20826	.23802	.26777	.29752	.32727	.35702	.38678	.41653	.44628
.37	.21405	.24463	.27521	.30579	.33636	.36694	.39752	.42810	.45868
.38	.21983	.25124	.28264	.31405	.34545	.37686	.40826	.43967	.47107
.39	.22562	.25785	.29008	.32231	.35455	.38678	.41901	.45124	.48347
.40	.23140	.26446	.29752	.33058	.36364	.39669	.42975	.46281	.49587
.41	.23719	.27107	.30496	.33884	.37273	.40661	.44049	.47438	.50826
.42	.24297	.27769	.31240	.34711	.38182	.41653	.45124	.48595	.52066
.43	.24876	.28430	.31983	.35537	.39091	.42645	.46198	.49752	.53306
.44	.25455	.29091	.32727	.36364	.40000	.43636	.47273	.50909	.54545
.45	.26033	.29752	.33471	.37190	.40909	.44628	.48347	.52066	.55785
.46	.26611	.30413	.34215	.38017	.41818	.45620	.49421	.53223	.57025
.47	.27190	.31074	.34959	.38843	.42727	.46611	.50496	.54380	.58264
.48	.27769	.31735	.35702	.39669	.43636	.47603	.51570	.55537	.59504
.49	.28347	.32397	.36446	.40496	.44545	.48595	.52645	.56694	.60744
.50	.28926	.33058	.37190	.41322	.45455	.49587	.53719	.57851	.61983

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second-feet	Hours								
	7	8	9	10	11	12	13	14	15
0.51	0.29504	0.33719	0.37934	0.42149	0.46364	0.50579	0.54793	0.59008	0.63223
.52	.30083	.34380	.38678	.42975	.47273	.51570	.55868	.60165	.64463
.53	.30661	.35041	.39421	.43802	.48182	.52562	.56942	.61322	.65702
.54	.31240	.35702	.40165	.44628	.49091	.53554	.58017	.62479	.66942
.55	.31818	.36364	.40909	.45455	.50000	.54545	.59091	.63636	.68182
.56	.32397	.37025	.41653	.46281	.50909	.55537	.60165	.64793	.69421
.57	.32975	.37686	.42397	.47107	.51818	.56529	.61240	.65950	.70661
.58	.33554	.38347	.43140	.47934	.52727	.57521	.62314	.67107	.71901
.59	.34132	.39008	.43884	.48760	.53636	.58512	.63388	.68264	.73140
.60	.34711	.39669	.44628	.49587	.54545	.59504	.64463	.69421	.74380
.61	.35289	.40331	.45372	.50413	.55455	.60496	.65537	.70579	.75620
.62	.35868	.40992	.46116	.51240	.56364	.61488	.66611	.71735	.76859
.63	.36446	.41653	.46859	.52066	.57273	.62479	.67686	.72893	.78099
.64	.37025	.42314	.47603	.52893	.58182	.63471	.68760	.74049	.79339
.65	.37603	.42975	.48347	.53719	.59091	.64463	.69835	.75207	.80579
.66	.38182	.43636	.49091	.54545	.60000	.65455	.70909	.76364	.81818
.67	.38760	.44297	.49835	.55372	.60909	.66446	.71983	.77521	.83058
.68	.39339	.44959	.50579	.56198	.61818	.67438	.73058	.78678	.84297
.69	.39917	.45620	.51322	.57025	.62727	.68430	.74132	.79835	.85537
.70	.40496	.46281	.52066	.57851	.63636	.69421	.75207	.80992	.86777
.71	.41074	.46942	.52810	.58678	.64545	.70413	.76281	.82149	.88017
.72	.41653	.47603	.53554	.59504	.65455	.71405	.77355	.83306	.89256
.73	.42231	.48264	.54297	.60331	.66364	.72397	.78430	.84463	.90496
.74	.42810	.48926	.55041	.61157	.67273	.73388	.79504	.85620	.91735
.75	.43388	.49587	.55785	.61983	.68182	.74380	.80579	.86777	.92975
.76	.43967	.50248	.56529	.62810	.69091	.75372	.81653	.87934	.94215
.77	.44545	.50909	.57273	.63636	.70000	.76364	.82727	.89091	.95455
.78	.45124	.51570	.58017	.64463	.70909	.77355	.83802	.90248	.96694
.79	.45702	.52231	.58760	.65289	.71818	.78347	.84876	.91405	.97934
.80	.46281	.52893	.59504	.66116	.72727	.79339	.85950	.92562	.99173
.81	.46859	.53554	.60248	.66942	.73636	.80331	.87025	.93719	1.00413
.82	.47438	.54215	.60992	.67769	.74545	.81322	.88099	.94876	1.01653
.83	.48017	.54876	.61735	.68595	.75455	.82314	.89173	.96033	1.02893
.84	.48595	.55537	.62479	.69421	.76364	.83306	.90248	.97190	1.04132
.85	.49173	.56198	.63223	.70248	.77273	.84297	.91322	.98347	1.05372
.86	.49752	.56859	.63967	.71074	.78182	.85289	.92397	.99504	1.06611
.87	.50331	.57521	.64711	.71901	.79091	.86281	.93471	1.00661	1.07851
.88	.50909	.58182	.65455	.72727	.80000	.87273	.94545	1.01818	1.09091
.89	.51488	.58843	.66198	.73554	.80909	.88264	.95620	1.02975	1.10331
.90	.52066	.59504	.66942	.74380	.81818	.89256	.96694	1.04132	1.11570
.91	.52645	.60165	.67686	.75207	.82727	.90248	.97769	1.05289	1.12810
.92	.53223	.60826	.68430	.76033	.83636	.91240	.98843	1.06446	1.14049
.93	.53802	.61488	.69173	.76859	.84545	.92231	.99917	1.07603	1.15289
.94	.54380	.62149	.69917	.77686	.85455	.93223	1.00992	1.08760	1.16529
.95	.54959	.62810	.70661	.78512	.86364	.94215	1.02066	1.09917	1.17769
.96	.55537	.63471	.71405	.79339	.87273	.95207	1.03140	1.11074	1.19008
.97	.56116	.64132	.72149	.80165	.88182	.96198	1.04215	1.12231	1.20248
.98	.56694	.64793	.72893	.80992	.89091	.97190	1.05289	1.13388	1.21488
.99	.57273	.65455	.73636	.81818	.90000	.98182	1.06364	1.14545	1.22727
1.00	.57851	.66116	.74380	.82645	.90909	.99173	1.07438	1.15702	1.23967

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second-feet	Hours								
	16	17	18	19	20	21	22	23	24
0.01	0.01322	0.01405	0.01488	0.01570	0.01653	0.01735	0.01818	0.01901	0.01983
.02	.02645	.02810	.02975	.03140	.03306	.03471	.03636	.03802	.03967
.03	.03967	.04215	.04463	.04711	.04959	.05207	.05455	.05702	.05950
.04	.05289	.05620	.05950	.06281	.06611	.06942	.07273	.07603	.07934
.05	.06611	.07025	.07438	.07851	.08264	.08678	.09091	.09504	.09917
.06	.07934	.08430	.08926	.09421	.09917	.10413	.10909	.11405	.11901
.07	.09256	.09835	.10412	.10992	.11570	.12149	.12727	.13306	.13884
.08	.10579	.11240	.11901	.12562	.13223	.13884	.14545	.15207	.15868
.09	.11901	.12645	.13388	.14132	.14876	.15620	.16364	.17107	.17851
.10	.13223	.14049	.14876	.15702	.16529	.17355	.18182	.19008	.19835
.11	.14545	.15455	.16364	.17273	.18182	.19091	.20000	.20909	.21818
.12	.15868	.16859	.17851	.18843	.19835	.20826	.21818	.22810	.23802
.13	.17190	.18264	.19339	.20413	.21488	.22562	.23636	.24711	.25785
.14	.18512	.19669	.20826	.21983	.23140	.24297	.25455	.26611	.27769
.15	.19835	.21074	.22314	.23554	.24793	.26033	.27273	.28512	.29752
.16	.21157	.22479	.23802	.25124	.26446	.27769	.29091	.30413	.31735
.17	.22479	.23884	.25289	.26694	.28099	.29504	.30909	.32314	.33719
.18	.23802	.25289	.26777	.28264	.29752	.31240	.32727	.34215	.35702
.19	.25124	.26694	.28264	.29835	.31405	.32975	.34545	.36116	.37686
.20	.26446	.28099	.29752	.31405	.33058	.34711	.36364	.38017	.39669
.21	.27769	.29504	.31240	.32975	.34711	.36446	.38182	.39917	.41653
.22	.29091	.30909	.32727	.34545	.36364	.38182	.40000	.41818	.43636
.23	.30413	.32314	.34215	.36116	.38017	.39917	.41818	.43719	.45620
.24	.31735	.33719	.35702	.37686	.39669	.41653	.43636	.45620	.47603
.25	.33058	.35124	.37190	.39256	.41322	.43388	.45455	.47521	.49587
.26	.34380	.36529	.38678	.40826	.42975	.45124	.47273	.49421	.51570
.27	.35702	.37934	.40165	.42397	.44628	.46859	.49091	.51322	.53554
.28	.37025	.39339	.41653	.43967	.46281	.48595	.50909	.53223	.55537
.29	.38347	.40744	.43140	.45537	.47934	.50331	.52727	.55124	.57521
.30	.39669	.42149	.44628	.47107	.49587	.52066	.54545	.57025	.59504
.31	.40992	.43554	.46116	.48678	.51240	.53802	.56364	.58926	.61488
.32	.42314	.44959	.47603	.50248	.52893	.55537	.58182	.60826	.63471
.33	.43636	.46364	.49091	.51818	.54545	.57273	.60000	.62727	.65455
.34	.44959	.47769	.50579	.53388	.56198	.59008	.61818	.64628	.67438
.35	.46281	.49173	.52066	.54959	.57851	.60744	.63636	.66529	.69421
.36	.47603	.50579	.53554	.56529	.59504	.62479	.65455	.68430	.71405
.37	.48926	.51983	.55041	.58099	.61157	.64215	.67273	.70331	.73388
.38	.50248	.53388	.56529	.59669	.62810	.65950	.69091	.72231	.75372
.39	.51570	.54793	.58017	.61240	.64463	.67686	.70909	.74132	.77355
.40	.52893	.56198	.59504	.62810	.66116	.69421	.72727	.76033	.79339
.41	.54215	.57603	.60992	.64380	.67769	.71157	.74545	.77934	.81322
.42	.55537	.59008	.62479	.65950	.69421	.72893	.76364	.79835	.83306
.43	.56859	.60413	.63967	.67521	.71074	.74628	.78182	.81735	.85289
.44	.58182	.61818	.65455	.69091	.72727	.76364	.80000	.83636	.87273
.45	.59504	.63223	.66942	.70661	.74380	.78099	.81818	.85537	.89256
.46	.60826	.64628	.68430	.72231	.76033	.79835	.83636	.87438	.91240
.47	.62149	.66033	.69917	.73802	.77686	.81570	.85455	.89339	.93223
.48	.63471	.67438	.71405	.75372	.79339	.83306	.87273	.91240	.95207
.49	.64793	.68843	.72893	.76942	.80992	.85041	.89091	.93140	.97190
.50	.66116	.70248	.74380	.78512	.82645	.86777	.90909	.95041	.99173

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second feet	Hour 16	17	18	19	20	21	22	23	24
0.51	0.67438	0.71653	0.75868	0.80083	0.84297	0.88512	0.92727	0.96942	1.01157
.52	.68760	.73058	.77355	.81653	.85950	.90248	.94545	.98843	1.03140
.53	.70083	.74463	.78843	.83223	.87603	.91983	.96364	1.00744	1.05124
.54	.71405	.75868	.80331	.84793	.89256	.93719	.98182	1.02645	1.07107
.55	.72727	.77273	.81818	.86364	.90909	.95455	1.00000	1.04545	1.09091
.56	.74049	.78678	.83306	.87934	.92562	.97190	1.01818	1.06446	1.11074
.57	.75372	.80083	.84793	.89504	.94215	.98926	1.03636	1.08347	1.13058
.58	.76694	.81487	.86281	.91074	.95868	1.00661	1.05455	1.10248	1.15041
.59	.78017	.82893	.87769	.92645	.97521	1.02397	1.07273	1.12149	1.17025
.60	.79339	.84297	.89256	.94215	.99173	1.04132	1.09091	1.14049	1.19008
.61	.80661	.85702	.90744	.95785	1.00826	1.05868	1.10909	1.15950	1.20992
.62	.81983	.87107	.92231	.97355	1.02479	1.07603	1.12727	1.17851	1.22975
.63	.83306	.88512	.93719	.98926	1.04132	1.09339	1.14545	1.19752	1.24959
.64	.84628	.89917	.95207	1.00496	1.05785	1.11074	1.16364	1.21653	1.26942
.65	.85950	.91322	.96694	1.02066	1.07438	1.12810	1.18182	1.23554	1.28926
.66	.87273	.92727	.98182	1.03636	1.09091	1.14545	1.20000	1.25455	1.30909
.67	.88595	.94132	.99669	1.05207	1.10744	1.16281	1.21818	1.27355	1.32893
.68	.89917	.95537	1.01157	1.06777	1.12397	1.18017	1.23636	1.29256	1.34876
.69	.91240	.96942	1.02645	1.08347	1.14050	1.19752	1.25455	1.31157	1.36860
.70	.92562	.98347	1.04132	1.09917	1.15702	1.21488	1.27273	1.33058	1.38843
.71	.93884	.99752	1.05620	1.11488	1.17355	1.23223	1.29091	1.34959	1.40826
.72	.95207	1.01157	1.07107	1.13058	1.19008	1.24959	1.30909	1.36860	1.42810
.73	.96529	1.02562	1.08595	1.14628	1.20661	1.26694	1.32727	1.38760	1.44793
.74	.97851	1.03967	1.10083	1.16198	1.22314	1.28430	1.34545	1.40661	1.46777
.75	.99173	1.05372	1.11570	1.17769	1.23967	1.30165	1.36364	1.42562	1.48760
.76	1.00496	1.06777	1.13058	1.19339	1.25620	1.31901	1.38182	1.44463	1.50744
.77	1.01818	1.08182	1.14545	1.20909	1.27273	1.33636	1.40000	1.46364	1.52727
.78	1.03140	1.09587	1.16033	1.22479	1.28926	1.35372	1.41818	1.48264	1.54711
.79	1.04463	1.10992	1.17521	1.24050	1.30579	1.37107	1.43636	1.50165	1.56694
.80	1.05785	1.12397	1.19008	1.25620	1.32231	1.38843	1.45455	1.52066	1.58678
.81	1.07107	1.13802	1.20496	1.27190	1.33884	1.40579	1.47273	1.53967	1.60661
.82	1.08430	1.15207	1.21983	1.28760	1.35537	1.42314	1.49091	1.55868	1.62645
.83	1.09752	1.16612	1.23471	1.30331	1.37190	1.44050	1.50909	1.57769	1.64628
.84	1.11074	1.18017	1.24959	1.31901	1.38843	1.45785	1.52727	1.59669	1.66611
.85	1.12397	1.19421	1.26446	1.33471	1.40496	1.47521	1.54545	1.61570	1.68595
.86	1.13719	1.20826	1.27934	1.35041	1.42149	1.49256	1.56364	1.63471	1.70579
.87	1.15041	1.22231	1.29421	1.36612	1.43802	1.50992	1.58182	1.65372	1.72562
.88	1.16364	1.23636	1.30909	1.38182	1.45455	1.52727	1.60000	1.67273	1.74545
.89	1.17686	1.25041	1.32397	1.39752	1.47107	1.54463	1.61818	1.69174	1.76529
.90	1.19008	1.26446	1.33884	1.41322	1.48760	1.56198	1.63636	1.71074	1.78512
.91	1.20331	1.27851	1.35372	1.42893	1.50413	1.57934	1.65455	1.72975	1.80496
.92	1.21653	1.29256	1.36860	1.44463	1.52066	1.59669	1.67273	1.74876	1.82479
.93	1.22975	1.30661	1.38347	1.46033	1.53719	1.61405	1.69091	1.76777	1.84463
.94	1.24297	1.32066	1.39835	1.47603	1.55372	1.63140	1.70909	1.78678	1.86446
.95	1.25620	1.33471	1.41322	1.49174	1.57025	1.64876	1.72727	1.80579	1.88430
.96	1.26942	1.34876	1.42810	1.50744	1.58678	1.66611	1.74545	1.82479	1.90413
.97	1.28264	1.36281	1.44297	1.52314	1.60330	1.68347	1.76364	1.84380	1.92397
.98	1.29587	1.37686	1.45785	1.53884	1.61983	1.70083	1.78182	1.86281	1.94380
.99	1.30909	1.39091	1.47273	1.55455	1.63636	1.71818	1.80000	1.88182	1.96364
1.00	1.32231	1.40496	1.48760	1.57025	1.65289	1.73554	1.81818	1.90083	1.98347

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second-feet	Days of 24 hours								
	2	3	4	5	6	7	8	9	10
0.01	0.03967	0.05950	0.07934	0.09917	0.11901	0.13884	0.15868	0.17851	0.19835
.02	.07934	.11901	.15868	.19835	.23802	.27769	.31735	.35702	.39669
.03	.11901	.17851	.23802	.29752	.35702	.41653	.47603	.53554	.59504
.04	.15868	.23802	.31735	.39669	.47603	.55537	.63471	.71405	.79339
.05	.19835	.29752	.39669	.49587	.59504	.69421	.79339	.89256	.99173
.06	.23802	.35702	.47603	.59504	.71405	.83306	.95207	1.07107	1.19008
.07	.27769	.41653	.55537	.69421	.83306	.97190	1.11074	1.24959	1.38842
.08	.31735	.47603	.63471	.79339	.95207	1.11074	1.26942	1.42810	1.58678
.09	.35702	.53554	.71405	.89256	1.07107	1.24959	1.42810	1.60661	1.78512
.10	.39669	.59504	.79339	.99173	1.19008	1.38843	1.58678	1.78512	1.98347
.11	.43636	.65455	.87273	1.09091	1.30909	1.52727	1.74545	1.96364	2.18182
.12	.47603	.71405	.95207	1.19008	1.42810	1.66611	1.90413	2.14215	2.38016
.13	.51570	.77355	1.03140	1.28925	1.54711	1.80496	2.06281	2.32066	2.57851
.14	.55537	.83306	1.11074	1.38842	1.66611	1.94380	2.22149	2.49917	2.77686
.15	.59504	.89256	1.19008	1.48760	1.78512	2.08264	2.38017	2.67769	2.97520
.16	.63471	.95207	1.26942	1.58678	1.90413	2.22149	2.53884	2.85620	3.17355
.17	.67438	1.01157	1.34876	1.68595	2.02314	2.36033	2.69752	3.03471	3.37190
.18	.71405	1.07107	1.42810	1.78512	2.14215	2.49917	2.85620	3.21322	3.57025
.19	.75372	1.13058	1.50744	1.88430	2.26116	2.63802	3.01487	3.39173	3.76859
.20	.79339	1.19008	1.58678	1.98347	2.38017	2.77686	3.17355	3.57025	3.96694
.21	.83306	1.24959	1.66611	2.08264	2.49917	2.91570	3.33223	3.74876	4.16529
.22	.87273	1.30909	1.74545	2.18182	2.61818	3.05455	3.49091	3.92727	4.36363
.23	.91240	1.36859	1.82479	2.28099	2.73719	3.19339	3.64959	4.10578	4.56198
.24	.95207	1.42810	1.90413	2.38016	2.85620	3.33223	3.80826	4.28430	4.76033
.25	.99173	1.48760	1.98347	2.47934	2.97521	3.47107	3.96694	4.46281	4.95867
.26	1.03140	1.54711	2.06281	2.57851	3.09421	3.60992	4.12562	4.64132	5.15702
.27	1.07107	1.60661	2.14215	2.67768	3.21322	3.74876	4.28430	4.81983	5.35537
.28	1.11074	1.66611	2.22149	2.77686	3.33223	3.88760	4.44297	4.99835	5.55372
.29	1.15041	1.72562	2.30083	2.87603	3.45124	4.02645	4.60165	5.17686	5.75206
.30	1.19008	1.78512	2.38017	2.97520	3.57025	4.16529	4.76033	5.35537	5.95041
.31	1.22975	1.84463	2.45950	3.07438	3.68925	4.30413	4.91901	5.53388	6.14876
.32	1.26942	1.90413	2.53884	3.17355	3.80826	4.44297	5.07769	5.71240	6.34710
.33	1.30909	1.96364	2.61818	3.27273	3.92727	4.58182	5.23636	5.89091	6.54545
.34	1.34876	2.02314	2.69752	3.37190	4.04628	4.72066	5.39504	6.06942	6.74380
.35	1.38843	2.08264	2.77686	3.47107	4.16529	4.85950	5.55372	6.24793	6.94215
.36	1.42810	2.14215	2.85620	3.57025	4.28430	4.99835	5.71240	6.42645	7.14049
.37	1.46777	2.20165	2.93554	3.66942	4.40331	5.13719	5.87107	6.60496	7.33884
.38	1.50744	2.26116	3.01487	3.76859	4.52231	5.27603	6.02975	6.78347	7.53719
.39	1.54711	2.32066	3.09421	3.86777	4.64132	5.41487	6.18843	6.96198	7.73553
.40	1.58678	2.38017	3.17355	3.96694	4.76033	5.55372	6.34711	7.14049	7.93388
.41	1.62645	2.43967	3.25289	4.06611	4.87934	5.69256	6.50578	7.31901	8.13223
.42	1.66611	2.49917	3.33223	4.16529	4.99835	5.83140	6.66446	7.49752	8.33057
.43	1.70579	2.55868	3.41157	4.26446	5.11735	5.97025	6.82314	7.67603	8.52892
.44	1.74545	2.61818	3.49091	4.36363	5.23636	6.10909	6.98182	7.85455	8.72727
.45	1.78512	2.67769	3.57025	4.46281	5.35537	6.24793	7.14049	8.03305	8.92561
.46	1.82479	2.73719	3.64959	4.56198	5.47438	6.38678	7.29917	8.21157	9.12396
.47	1.86446	2.79669	3.72893	4.66115	5.59339	6.52562	7.45785	8.39008	9.32231
.48	1.90413	2.85620	3.80826	4.76033	5.71240	6.66446	7.61653	8.56859	9.52066
.49	1.94380	2.91570	3.88760	4.85950	5.83140	6.80331	7.77521	8.74711	9.71900
.50	1.98347	2.97521	3.96694	4.95867	5.95041	6.94215	7.93388	8.92561	9.91735

141

Table 1. Acre-feet equivalent to a given number of second-feet flowing for a given length of time (Cont'd).

Second-feet	Days of 24 hours								
	2	3	4	5	6	7	8	9	10
0.51	2.02314	3.03471	4.04628	5.05785	6.06942	7.08099	8.09256	9.10413	10.11570
.52	2.06281	3.09421	4.12562	5.15702	6.18843	7.21983	8.25124	9.28264	10.31404
.53	2.10248	3.15372	4.20496	5.25619	6.30744	7.35868	8.40992	9.46116	10.51239
.54	2.14215	3.21322	4.28430	5.35537	6.42645	7.49752	8.56859	9.63967	10.71074
.55	2.18182	3.27273	4.36364	5.45454	6.54545	7.63636	8.72727	9.81818	10.90909
.56	2.22149	3.33223	4.44297	5.55372	6.66446	7.77521	8.88595	9.99669	11.10743
.57	2.26116	3.39173	4.52231	5.65289	6.78347	7.91405	9.04463	10.17521	11.30578
.58	2.30083	3.45124	4.60165	5.75206	6.90248	8.05289	9.20331	10.35372	11.50413
.59	2.34049	3.51074	4.68099	5.85124	7.02149	8.19173	9.36198	10.53223	11.70247
.60	2.38017	3.57025	4.76033	5.95041	7.14049	8.33058	9.52066	10.71074	11.90082
.61	2.41983	3.62975	4.83967	6.04958	7.25950	8.46942	9.67934	10.88925	12.09917
.62	2.45950	3.68925	4.91901	6.14876	7.37851	8.60826	9.83802	11.06777	12.29751
.63	2.49917	3.74876	4.99835	6.24793	7.49752	8.74711	9.99669	11.24628	12.49586
.64	2.53884	3.80826	5.07769	6.34710	7.61653	8.88595	10.15537	11.42479	12.69421
.65	2.57851	3.86777	5.15702	6.44628	7.73554	9.02479	10.31405	11.60331	12.89255
.66	2.61818	3.92727	5.23636	6.54545	7.85455	9.16364	10.47273	11.78182	13.09090
.67	2.65785	3.98678	5.31570	6.64462	7.97355	9.30248	10.63140	11.96033	13.28925
.68	2.69752	4.04628	5.39504	6.74380	8.09256	9.44132	10.79008	12.13884	13.48760
.69	2.73719	4.10578	5.47438	6.84297	8.21157	9.58016	10.94876	12.31735	13.68594
.70	2.77686	4.16529	5.55372	6.94215	8.33058	9.71901	11.10744	12.49587	13.88429
.71	2.81653	4.22479	5.63306	7.04132	8.44959	9.85785	11.26611	12.67438	14.08264
.72	2.85620	4.28430	5.71240	7.14049	8.56859	9.99669	11.42479	12.85289	14.28099
.73	2.89587	4.34380	5.79173	7.23967	8.68760	10.13554	11.58347	13.03140	14.47933
.74	2.93554	4.40331	5.87107	7.33884	8.80661	10.27438	11.74215	13.20992	14.67768
.75	2.97521	4.46281	5.95041	7.43801	8.92562	10.41322	11.90083	13.38843	14.87603
.76	3.01487	4.52231	6.02975	7.53719	9.04463	10.55207	12.05950	13.56694	15.07437
.77	3.05455	4.58182	6.10909	7.63636	9.16364	10.69091	12.21818	13.74545	15.27272
.78	3.09421	4.64132	6.18843	7.73553	9.28264	10.82975	12.37686	13.92397	15.47107
.79	3.13388	4.70083	6.26777	7.83471	9.40165	10.96859	12.53554	14.10248	15.66941
.80	3.17355	4.76033	6.34711	7.93388	9.52066	11.10744	12.69421	14.28099	15.86776
.81	3.21322	4.81983	6.42645	8.03305	9.63967	11.24628	12.85289	14.45950	16.06611
.82	3.25289	4.87934	6.50578	8.13223	9.75868	11.38512	13.01157	14.63801	16.26445
.83	3.29256	4.93884	6.58512	8.23140	9.87769	11.52397	13.17025	14.81653	16.46280
.84	3.33223	4.99835	6.66446	8.33057	9.99669	11.66281	13.32893	14.99504	16.66115
.85	3.37190	5.05785	6.74380	8.42975	10.11570	11.80165	13.48760	15.17355	16.85949
.86	3.41157	5.11735	6.82314	8.52892	10.23471	11.94049	13.64628	15.35207	17.05784
.87	3.45124	5.17686	6.90248	8.62809	10.35372	12.07934	13.80496	15.53058	17.25619
.88	3.49091	5.23636	6.98182	8.72727	10.47273	12.21818	13.96363	15.70909	17.45454
.89	3.53058	5.29587	7.06116	8.82644	10.59173	12.35702	14.12231	15.88760	17.65288
.90	3.57025	5.35537	7.14049	8.92561	10.71074	12.49587	14.28099	16.06611	17.85123
.91	3.60992	5.41487	7.21983	9.02479	10.82975	12.63471	14.43967	16.24463	18.04958
.92	3.64959	5.47438	7.29917	9.12396	10.94876	12.77355	14.59835	16.42314	18.24792
.93	3.68925	5.53388	7.37851	9.22313	11.06777	12.91240	14.75702	16.60165	18.44627
.94	3.72893	5.59339	7.45785	9.32231	11.18678	13.05124	14.91570	16.78016	18.64462
.95	3.76859	5.65289	7.53719	9.42148	11.30578	13.19008	15.07438	16.95868	18.84297
.96	3.80826	5.71240	7.61653	9.52066	11.42479	13.32893	15.23306	17.13719	19.04131
.97	3.84793	5.77190	7.69587	9.61983	11.54380	13.46777	15.39173	17.31570	19.23966
.98	3.88760	5.83140	7.77521	9.71900	11.66281	13.60661	15.55041	17.49421	19.43801
.99	3.92727	5.89091	7.85455	9.81818	11.78182	13.74545	15.70909	17.67273	19.63635
1.00	3.96694	5.95041	7.93388	9.91735	11.90083	13.88430	15.86777	17.85124	19.83470

Table 3 - Three-halves powers of numbers, useful in determining $H^{3/2}$, $h^{3/2}$ or $(H + H)^{3/2}$.

No.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.0000	.0010	.0028	.0052	.0080	.0112	.0147	.0185	.0226	.0270
.1	.0316	.0365	.0416	.0469	.0524	.058	.0640	.0701	.0764	.0828
.2	.0894	.0962	.1032	.1103	.1176	.1250	.1326	.1403	.1482	.1562
.3	.1643	.1726	.1810	.1896	.1983	.2071	.2160	.2251	.2342	.2436
.4	.2530	.2625	.2722	.2820	.2919	.3019	.3120	.3222	.3325	.3430
.5	.3536	.3642	.3750	.3858	.3968	.4079	.4191	.4303	.4417	.4532
.6	.4648	.4764	.4882	.5000	.5120	.5240	.5362	.5484	.5607	.5732
.7	.5857	.5983	.6109	.6237	.6366	.6495	.6626	.6757	.6889	.7022
.8	.7155	.7290	.7425	.7562	.7699	.7837	.7975	.8115	.8255	.8396
.9	.8538	.8681	.8824	.8969	.9144	.9259	.9406	.9553	.9702	.9850
1.0	1.000	1.015	1.030	1.045	1.061	1.076	1.091	1.107	1.122	1.138
1.1	1.154	1.170	1.185	1.201	1.217	1.233	1.249	1.266	1.282	1.298
1.2	1.314	1.331	1.346	1.364	1.381	1.398	1.414	1.431	1.448	1.465
1.3	1.482	1.499	1.517	1.534	1.55	1.569	1.586	1.604	1.621	1.639
1.4	1.657	1.674	1.692	1.710	1.728	1.746	1.764	1.782	1.801	1.819
1.5	1.837	1.856	1.874	1.892	1.911	1.930	1.948	1.967	1.986	2.005
1.6	2.024	2.043	2.062	2.081	2.100	2.120	2.139	2.158	2.178	2.197
1.7	2.216	2.236	2.256	2.276	2.295	2.315	2.335	2.355	2.375	2.395
1.8	2.415	2.435	2.455	2.476	2.496	2.516	2.537	2.557	2.578	2.598
1.9	2.619	2.640	2.660	2.681	2.702	2.723	2.744	2.765	2.786	2.807
2.0	2.828	2.850	2.871	2.892	2.914	2.935	2.957	2.978	3.000	3.022
2.1	3.043	3.065	3.087	3.109	3.131	3.153	3.174	3.197	3.219	3.241
2.2	3.263	3.285	3.308	3.330	3.352	3.375	3.398	3.420	3.443	3.465
2.3	3.488	3.511	3.534	3.557	3.580	3.602	3.626	3.649	3.672	3.695
2.4	3.718	3.741	3.765	3.788	3.811	3.835	3.858	3.882	3.906	3.929
2.5	3.953	3.977	4.000	4.024	4.048	4.072	4.096	4.120	4.144	4.168
2.6	4.192	4.217	4.241	4.265	4.290	4.314	4.338	4.363	4.387	4.412
2.7	4.437	4.461	4.486	4.511	4.536	4.560	4.585	4.610	4.635	4.660
2.8	4.685	4.710	4.736	4.761	4.786	4.811	4.837	4.862	4.888	4.913
2.9	4.938	4.964	4.990	5.015	5.041	5.067	5.093	5.118	5.144	5.170
3.0	5.196	5.222	5.248	5.274	5.300	5.327	5.353	5.379	5.405	5.432
3.1	5.458	5.484	5.511	5.538	5.564	5.591	5.617	5.644	5.671	5.698
3.2	5.724	5.751	5.778	5.805	5.832	5.859	5.886	5.913	5.940	5.968
3.3	5.995	6.022	6.049	6.077	6.104	6.132	6.159	6.186	6.214	6.242
3.4	6.269	6.297	6.325	6.352	6.380	6.408	6.436	6.464	6.492	6.520

Table 3. Three-halves powers of numbers, useful in determining $H^{3/2}$, $h^{3/2}$ or $(H + h)^{3/2}$. – Continued

No.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
3.5	6.548	6.576	6.604	6.632	6.660	6.689	6.717	6.745	6.774	[illegible]
3.6	6.830	6.859	6.888	6.916	6.945	6.973	7.002	7.031	7.060	[illegible]
3.7	7.117	7.146	7.175	7.204	7.233	7.262	7.291	7.320	7.349	7.378
3.8	7.408	7.437	7.466	7.495	7.525	7.554	7.584	7.613	[illegible]	[illegible]
3.9	7.702	7.732	7.761	7.791	7.821	7.850	7.880	7.910	[illegible]	7.970
4.0	8.000	8.030	8.060	8.090	8.120	8.150	8.181	8.211	[illegible]	[illegible]
4.1	8.302	8.332	8.363	8.393	8.424	8.454	8.485	8.515	[illegible]	8.577
4.2	8.607	8.638	8.669	8.700	8.731	8.762	8.793	8.824	[illegible]	[illegible]
4.3	8.917	8.948	8.979	9.010	9.041	9.073	9.104	9.135	9.167	9.198
4.4	9.230	9.261	9.292	9.324	9.356	9.387	9.419	9.451	[illegible]	9.514
4.5	9.546	9.578	9.610	9.642	9.674	9.706	9.738	9.770	[illegible]	[illegible]
4.6	9.866	9.898	9.930	9.963	9.995	10.03	10.06	10.09	10.12	10.16
4.7	10.19	10.22	10.25	10.29	10.32	10.35	10.39	10.42	10.45	10.48
4.8	10.52	10.55	10.58	10.62	10.65	10.68	10.71	10.75	10.78	10.81
4.9	10.85	10.88	10.91	10.95	10.98	11.01	11.05	11.08	11.11	11.15
5.0	11.18	11.21	11.25	11.28	11.31	11.35	11.38	11.42	11.45	11.48
5.1	11.52	11.55	11.59	11.62	11.65	11.69	11.72	11.76	11.79	11.82
5.2	11.86	11.89	11.93	11.96	11.99	12.03	12.06	12.10	12.13	12.17
5.3	12.20	12.24	12.27	12.31	12.34	12.37	12.41	12.44	12.48	12.51
5.4	12.55	12.58	12.62	12.65	12.69	12.72	12.76	12.79	[illegible]	[illegible]
5.5	12.90	12.93	12.97	13.00	13.04	13.07	13.11	13.15	[illegible]	[illegible]
5.6	13.25	13.29	13.32	13.36	13.39	13.43	13.47	13.50	[illegible]	[illegible]
5.7	13.61	13.64	13.68	13.72	13.75	13.79	13.82	13.86	[illegible]	[illegible]
5.8	13.97	14.00	14.04	14.08	14.11	14.15	14.19	14.22	[illegible]	[illegible]
5.9	14.33	14.37	14.40	14.44	14.48	14.51	14.55	14.59	[illegible]	[illegible]
6.0	14.70	14.73	14.77	14.81	14.84	14.88	14.92	14.95	14.99	15.03
6.1	15.07	15.10	15.14	15.18	15.21	15.25	15.29	15.33	15.36	15.40
6.2	15.44	15.48	15.51	15.55	15.59	15.62	15.66	15.70	15.74	15.78
6.3	15.81	15.85	15.89	15.93	15.96	16.00	16.04	16.08	[illegible]	16.15
6.4	16.19	16.23	16.27	16.30	16.34	16.38	16.42	16.46	16.50	16.53

Table 4. Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from formula $A=3.33(L-0.2H)H^{3/2}$.

Head *H*, feet	Length of weir, *L*, feet										
	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
0.01	0.002	0.003	0.005	0.007	0.010	0.013	0.016	0.020	0.023	0.027	0.030
.02	.005	.009	.014	.019	.028	.037	.047	.056	.066	.075	.085
.03	.009	.017	.026	.035	.052	.069	.086	.104	.121	.138	.155
.04	.013	.026	.040	.053	.079	.106	.133	.159	.186	.213	.240
.05	.018	.037	.055	.074	.111	.148	.186	.223	.260	.297	.334
.06	.024	.048	.072	.097	.146	.195	.244	.293	.342	.391	.439
.07	.030	.061	.092	.122	.184	.246	.308	.369	.431	.493	.554
.08	.036	.074	.112	.149	.225	.300	.375	.451	.526	.601	.676
.09	.043	.088	.133	.178	.268	.358	.448	.538	.628	.718	.807
.10	.051	.103	.156	.208	.314	.419	.524	.630	.735	.840	.945
.11	.058	.119	.179	.240	.362	.483	.605	.726	.848	.969	1.09
.12	.066	.135	.204	.274	.412	.550	.689	.827	.966	1.10	1.24
.13	.074	.152	.230	.308	.464	.620	.776	.933	1.09	1.24	1.40
.14	.082	.169	.257	.344	.518	.693	.867	1.04	1.22	1.39	1.56
.15	.091	.188	.284	.381	.575	.768	.962	1.15	1.35	1.54	1.74
.16	.100	.206	.313	.419	.632	.845	1.06	1.27	1.48	1.70	1.91
.17	.109	.225	.342	.459	.692	.926	1.16	1.39	1.63	1.86	2.09
.18	.122	.245	.372	.499	.754	1.01	1.26	1.52	1.77	2.02	2.28
.19	.132	.265	.403	.541	.817	1.09	1.37	1.64	1.92	2.20	2.47
.20	.142	.286	.435	.584	.881	1.18	1.48	1.78	2.07	2.37	2.67
.21	.152	.307	.467	.627	.948	1.27	1.59	1.91	2.23	2.55	2.87
.22	.162	.328	.500	.672	1.02	1.36	1.70	2.05	2.39	2.73	3.08
.23	.173	.350	.534	.718	1.08	1.45	1.82	2.19	2.55	2.92	3.29
.24	.18[illegible]	.373	.568	.764	1.16	1.55	1.94	2.33	2.72	3.11	3.50
.25	.197	.395	.604	.811	1.23	1.64	2.06	2.48	2.89	3.31	3.72
.26		.419	.639	.860	1.30	1.74	2.18	2.63	3.07	3.51	3.95
.27		.442	.675	.909	1.38	1.84	2.31	2.78	3.25	3.71	4.18
.28		.466	.712	.959	1.45	1.95	2.44	2.93	3.43	3.92	4.41
.29		.490	.750	1.01	1.53	2.05	2.57	3.09	3.61	4.13	4.65
.30		.514	.788	1.06	1.61	2.16	2.70	3.25	3.80	4.34	4.89
.31		.539	.827	1.11	1.69	2.26	2.84	3.41	3.99	4.56	5.14
.32		.564	.866	1.17	1.77	2.37	2.98	3.58	4.18	4.78	5.39
.33		.590	.905	1.22	1.85	2.48	3.12	3.75	4.38	5.01	5.64
.34		.615	.945	1.28	1.94	2.60	3.26	3.92	4.58	5.24	5.90
.35		[illegible]	.986	1.33	2.02	2.71	3.40	4.09	4.78	5.47	6.16
.36		[illegible]	1.03	1.39	2.11	2.82	3.54	4.26	4.98	5.70	6.42
.37		.719	1.07	1.44	2.19	2.94	3.69	4.44	5.19	5.94	6.69
.38		[illegible]	1.11	1.50	2.28	3.06	3.84	4.62	5.40	6.18	6.96
.39		[illegible]	1.15	1.56	2.37	3.18	3.99	4.80	5.61	6.42	7.24
.40		.807	1.20	1.62	2.46	3.30	4.14	4.99	5.83	6.67	7.51
.41		[illegible]	1.24	1.68	2.55	3.42	4.30	5.17	6.05	6.92	7.80
.42		[illegible]	1.28	1.74	2.64	3.55	4.46	5.36	6.27	7.18	8.08
.43		[illegible]	1.33	1.80	2.74	3.68	4.61	5.55	6.49	7.43	8.37
.44		[illegible]	1.37	1.86	2.83	3.80	4.77	5.75	6.72	7.69	8.66
.45		[illegible]	1.42	1.92	2.92	3.93	4.94	5.94	6.95	7.95	8.96
.46		[illegible]	1.46	1.98	3.02	4.06	5.10	6.14	7.18	8.22	9.25
.47		1.01	1.51	2.05	3.12	4.19	5.26	6.34	7.41	8.48	9.56
.48		1.04	1.55	2.11	3.22	4.32	5.43	6.54	7.65	8.75	9.86
.49		1.08	1.60	2.17	3.31	4.46	5.60	6.74	7.88	9.03	10.17
.50		1.11	1.65	2.24	3.41	4.59	5.77	6.95	8.12	9.30	10.48

145

Table 4. Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from formula $Q=3.33(L-0.2H)H^{3/2}$ (Cont'd).

Head H, feet	Length of weir L, feet								
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
0.51	1.70	2.30	3.52	4.73	5.94	7.15	8.37	9.58	10.8
.52	1.74	2.37	3.62	4.86	6.11	7.36	8.61	9.86	11.1
.53	1.79	2.43	3.72	5.00	6.29	7.57	8.86	10.1	11.4
.54	1.84	2.50	3.82	5.14	6.46	7.79	9.11	10.4	11.8
.55	1.89	2.57	3.92	5.28	6.64	8.00	9.36	10.7	12.1
.56	1.94	2.64	4.03	5.43	6.82	8.22	9.61	11.0	12.4
.57	1.99	2.70	4.14	5.57	7.00	8.44	9.87	11.3	12.7
.58	2.04	2.77	4.24	5.71	7.18	8.66	10.1	11.6	13.1
.59	2.08	2.84	4.35	5.86	7.37	8.88	10.4	11.9	13.4
.60	2.14	2.91	4.46	6.00	7.55	9.10	10.6	12.2	13.7
.61	2.19	2.98	4.57	6.15	7.74	9.32	10.9	12.5	14.1
.62	2.24	3.05	4.68	6.30	7.93	9.55	11.2	12.8	14.4
.63	2.29	3.12	4.79	6.45	8.12	9.78	11.4	13.1	14.8
.64	2.34	3.19	4.90	6.60	8.31	10.0	11.7	13.4	15.1
.65	2.39	3.26	5.01	6.75	8.50	10.2	12.0	13.7	15.5
.66	2.44	3.34	5.12	6.91	8.69	10.5	12.3	14.0	15.8
.67	2.50	3.41	5.23	7.06	8.89	10.7	12.5	14.4	16.2
.68	2.55	3.58	5.35	7.22	9.08	11.0	12.8	14.7	16.6
.69	2.60	3.66	5.46	7.37	9.28	11.2	13.1	15.0	16.9
.70	2.65	3.74	5.58	7.53	9.48	11.4	13.4	15.3	17.3
.71	2.70	3.82	5.69	7.69	9.68	11.7	13.7	15.7	17.6
.72	2.76	3.90	5.81	7.84	9.88	11.9	13.9	16.0	18.0
.73	2.81	3.98	5.93	8.00	10.1	12.2	14.2	16.3	18.4
.74	2.87	4.06	6.05	8.16	10.3	12.4	14.5	16.6	18.8
.75	2.92	4.14	6.16	8.33	10.5	12.7	14.8	17.0	19.1
.76		4.22	6.28	8.49	10.7	12.9	15.1	17.3	19.5
.77		4.30	6.40	8.65	10.9	13.2	15.4	17.7	19.9
.78		4.38	6.52	8.82	11.1	13.4	15.7	18.0	20.3
.79		4.46	6.64	8.98	11.3	13.7	16.0	18.3	20.7
.80		4.54	6.77	9.15	11.5	13.9	16.3	18.7	21.1
.81		4.62	6.89	9.32	11.7	14.2	16.6	19.0	21.5
.82		4.70	7.01	9.48	12.0	14.4	16.9	19.4	21.8
.83		4.78	7.14	9.65	12.2	14.7	17.2	19.7	22.2
.84		4.87	7.26	9.82	12.4	15.0	17.5	20.1	22.6
.85		4.96	7.38	10.0	12.6	15.2	17.8	20.4	23.0
.86		5.05	7.51	10.2	12.8	15.5	18.1	20.8	23.4
.87		5.14	7.64	10.3	13.0	15.7	18.4	21.1	23.8
.88		5.23	7.76	10.5	13.3	16.0	18.8	21.5	24.3
.89		5.32	7.89	10.7	13.5	16.3	19.1	21.9	24.7
.90		5.41	8.02	10.9	13.7	16.5	19.4	22.2	25.1
.91		5.50	8.15	11.0	13.9	16.8	19.7	22.6	25.5
.92		5.59	8.28	11.2	14.2	17.1	20.0	23.0	25.9
.93		5.68	8.40	11.4	14.4	17.4	20.4	23.3	26.3
.94		5.77	8.53	11.6	14.6	17.6	20.7	23.7	26.7
.95		5.86	8.66	11.7	14.8	17.9	21.0	24.1	27.2
.96		5.95	8.80	11.9	15.1	18.2	21.3	24.5	27.6
.97		6.04	8.93	12.1	15.3	18.5	21.7	24.8	28.0
.98		6.13	9.06	12.3	15.5	18.8	22.0	25.2	28.4
.99		6.22	9.19	12.5	15.8	19.0	22.3	25.6	28.9
1.00		6.31	9.32	12.7	16.0	19.3	22.6	26.0	29.3

Table 4. Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from formula $Q=3.33(L-0.2H)H^{3/2}$ (Cont'd).

Head *H*, feet	Length of weir *L*, feet						
	3.0	4.0	5.0	6.0	7.0	8.0	9.0
1.01	9.87	12.8	16.2	19.6	23.0	26.4	29.8
1.02	10.0	13.0	16.5	19.9	23.3	26.7	30.2
1.03	10.2	13.2	16.7	20.2	23.6	27.1	30.6
1.04	10.3	13.4	16.9	20.5	24.0	27.5	31.1
1.05	10.4	13.6	17.2	20.7	24.3	27.9	31.5
1.06	10.6	13.8	17.4	21.0	24.7	28.3	31.9
1.07	10.8	14.0	17.6	21.3	25.0	28.7	32.4
1.08	10.9	14.1	17.9	21.6	25.4	29.1	32.8
1.09	11.0	14.3	18.1	21.9	25.7	29.5	33.3
1.10	11.2	14.5	18.4	22.2	26.0	29.9	33.7
1.11	11.4	14.7	18.6	22.5	26.4	30.3	34.2
1.12	11.5	14.9	18.9	22.8	26.7	30.7	34.6
1.13	11.6	15.1	19.1	23.1	27.1	31.1	35.1
1.14	11.8	15.3	19.3	23.4	27.4	31.5	35.6
1.15	12.0	15.5	19.6	23.7	27.8	31.9	36.0
1.16	12.1	15.7	19.8	24.0	28.2	32.3	36.5
1.17	12.2	15.9	20.1	24.3	28.5	32.7	36.9
1.18	12.4	16.1	20.3	24.6	28.9	33.1	37.4
1.19	12.6	16.3	20.6	24.9	29.2	33.6	37.9
1.20	12.7	16.5	20.8	25.2	29.6	34.0	38.3
1.21	12.8	16.7	21.1	25.5	30.0	34.4	38.8
1.22	13.0	16.9	21.3	25.8	30.3	34.8	39.3
1.23	13.2	17.1	21.6	26.1	30.7	35.2	39.8
1.24	13.3	17.3	21.8	26.4	31.0	35.6	40.2
1.25	13.5	17.5	22.1	26.8	31.4	36.1	40.7
1.26	13.6	17.7	22.4	27.1	31.8	36.5	41.2
1.27	13.8	17.9	22.6	27.4	32.2	36.9	41.7
1.28	14.0	18.1	22.9	27.7	32.5	37.3	42.2
1.29	14.1	18.3	23.1	28.0	32.9	37.8	42.7
1.30	14.3	18.5	23.4	28.3	33.3	38.2	43.1
1.31	14.4	18.7	23.7	28.6	33.6	38.6	43.6
1.32	14.6	18.9	23.9	29.0	34.0	39.1	44.1
1.33	14.8	19.1	24.2	29.3	34.4	39.5	44.6
1.34	14.9	19.3	24.4	29.6	34.8	39.9	45.1
1.35	15.1	19.5	24.7	29.9	35.2	40.4	45.6
1.36	15.2	19.7	25.0	30.3	35.5	40.8	46.1
1.37	15.4	19.9	25.2	30.6	35.9	41.3	46.6
1.38	15.6	20.1	25.5	30.9	36.3	41.7	47.1
1.39	15.7	20.3	25.8	31.2	36.7	42.1	47.6
1.40	15.9	20.5	26.0	31.6	37.1	42.6	48.1
1.41	16.0	20.7	26.3	31.9	37.5	43.0	48.6
1.42	16.2	20.9	26.6	32.2	37.8	43.5	49.1
1.43	16.4	21.1	26.8	32.5	38.2	43.9	49.6
1.44	16.5	21.4	27.1	32.9	38.6	44.4	50.1
1.45	16.7	21.6	27.4	33.2	39.0	44.8	50.6
1.46	16.8	21.8	27.7	33.5	39.4	45.3	51.2
1.47	17.0	22.0	27.9	33.9	39.8	45.7	51.7
1.48	17.2	22.2	28.2	34.2	40.2	46.2	52.2
1.49	17.4	22.4	28.5	34.5	40.6	46.6	52.7
1.50	17.5	22.6	28.8	34.9	41.0	47.1	53.2

Table 4. Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from formula $Q=3.33(L-0.2H)H^{3/2}$ (Cont'd).

Head *H* feet	Length of weir *L*, feet					
	4.0	5.0	6.0	7.0	8.0	9.0
1.51	22.8	29.0	35.2	41.4	47.6	53.7
1.52	23.1	29.3	35.5	41.8	48.0	54.3
1.53	23.3	29.6	35.9	42.2	48.5	54.8
1.54	23.5	29.9	36.2	42.6	49.0	55.3
1.55	23.7	30.1	36.6	43.0	49.4	55.8
1.56	23.9	30.4	36.9	43.4	49.9	56.4
1.57	24.1	30.7	37.2	43.8	50.3	56.9
1.58	24.4	31.0	37.6	44.2	50.8	57.4
1.59	24.6	31.3	37.9	44.6	51.3	58.0
1.60	24.8	31.5	38.3	45.0	51.8	58.5
1.61	25.0	31.8	38.6	45.4	52.2	59.0
1.62	25.2	32.1	39.0	45.8	52.7	59.6
1.63	25.5	32.4	39.3	46.2	53.2	60.1
1.64	25.7	32.7	39.7	46.7	53.7	60.6
1.65	25.9	33.0	40.0	47.1	54.1	61.2
1.66	26.1	33.2	40.4	47.5	54.6	61.7
1.67	26.3	33.5	40.7	47.9	55.1	62.3
1.68	26.6	33.8	41.1	48.3	55.6	62.8
1.69	26.8	34.1	41.4	48.7	56.1	63.4
1.70	27.0	34.4	41.8	49.2	56.5	63.9
1.71	27.2	34.7	42.1	49.6	57.0	64.5
1.72	27.5	35.0	42.5	50.0	57.5	65.0
1.73	27.7	35.3	42.8	50.4	58.0	65.6
1.74	27.9	35.6	43.2	50.8	58.5	66.1
1.75	28.1	35.8	43.6	51.3	59.0	66.7
1.76	28.4	36.1	43.9	51.7	59.5	67.2
1.77	28.6	36.4	44.3	52.1	60.0	67.8
1.78	28.8	36.7	44.6	52.5	60.4	68.4
1.79	29.0	37.0	45.0	53.0	60.9	68.9
1.80	29.3	37.3	45.4	53.4	61.4	69.5
1.81	29.5	37.6	45.7	53.8	61.9	70.0
1.82	29.7	37.9	46.1	54.3	62.4	70.6
1.83	30.0	38.2	46.4	54.7	62.9	71.2
1.84	30.2	38.5	46.8	55.1	63.4	71.7
1.85	30.4	38.8	47.2	55.6	63.9	72.3
1.86	30.6	39.1	47.5	56.0	64.4	72.9
1.87	30.9	39.4	47.9	56.4	64.9	73.5
1.88	31.1	39.7	48.3	56.9	65.4	74.0
1.89	31.3	40.0	48.6	57.3	65.9	74.6
1.90	31.6	40.3	49.0	57.7	66.5	75.2
1.91	31.8	40.6	49.4	58.2	67.0	75.8
1.92	32.0	40.9	49.8	58.6	67.5	76.3
1.93	32.3	41.2	50.1	59.0	68.0	76.9
1.94	32.5	41.5	50.5	59.5	68.5	77.5
1.95	32.7	41.8	50.9	59.9	69.0	78.1
1.96	33.0	42.1	51.2	60.4	69.5	78.7
1.97	33.2	42.4	51.6	60.8	70.0	79.2
1.98	33.4	42.7	52.0	61.3	70.5	79.8
1.99	33.7	43.0	52.4	61.7	71.1	80.4
2.00	33.9	43.3	52.7	62.2	71.6	81.0

Table 4. Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from formula $Q=3.33(L-0.2H)H^{3/2}$ (Cont'd).

Head *H*, feet	Length of weir *L*, feet				
	5.0	6.0	7.0	8.0	9.0
2.01	43.6	53.1	62.6	72.1	81.6
2.02	43.9	53.5	63.1	72.6	82.2
2.03	44.2	53.9	63.5	73.1	82.8
2.04	44.6	54.3	64.0	73.7	83.4
2.05	44.9	54.6	64.4	74.2	84.0
2.06	45.2	55.0	64.9	74.7	84.6
2.07	45.5	55.4	65.3	75.2	85.2
2.08	45.8	55.8	65.8	75.8	85.7
2.09	46.1	56.2	66.2	76.3	86.4
2.10	46.4	56.5	66.7	76.8	87.0
2.11	46.7	56.9	67.1	77.3	87.5
2.12	47.0	57.3	67.6	77.9	88.2
2.13	47.4	57.7	68.1	78.4	88.8
2.14	47.7	58.1	68.5	78.9	89.4
2.15	48.0	58.5	69.0	79.5	90.0
2.16	48.3	58.9	69.4	80.0	90.6
2.17	48.6	59.2	69.9	80.5	91.2
2.18	48.9	59.6	70.4	81.1	91.8
2.19	49.2	60.0	70.8	81.6	92.4
2.20	49.5	60.4	71.3	82.1	93.0
2.21	49.9	60.8	71.7	82.7	93.6
2.22	50.2	61.2	72.2	83.2	94.2
2.23	50.5	61.6	72.7	83.8	94.9
2.24	50.8	62.0	73.1	84.3	95.5
2.25	51.1	62.4	73.6	84.9	96.1
2.26	51.5	62.8	74.1	85.4	96.7
2.27	51.8	63.2	74.6	85.9	97.3
2.28	52.1	63.6	75.0	86.5	97.9
2.29	52.4	64.0	75.5	87.0	98.6
2.30	52.7	64.3	76.0	87.6	99.2
2.31	53.1	64.7	76.4	88.1	99.8
2.32	53.4	65.1	76.9	88.7	100.4
2.33	53.7	65.5	77.4	89.2	101.1
2.34	54.0	65.9	77.9	89.8	101.7
2.35	54.3	66.3	78.3	90.3	102.3
2.36	54.7	66.7	78.8	90.9	103.0
2.37	55.0	67.1	79.3	91.4	103.6
2.38	55.3	67.5	79.8	92.0	104.2
2.39	55.6	67.9	80.2	92.6	104.9
2.40	56.0	68.3	80.7	93.1	105.5
2.41	56.3	68.7	81.2	93.7	106.1
2.42	56.6	69.1	81.7	94.2	106.8
2.43	56.9	69.6	82.2	94.8	107.4
2.44	57.3	70.0	82.6	95.3	108.0
2.45	57.6	70.4	83.1	95.9	108.7
2.46	57.9	70.8	83.6	96.5	109.3
2.47	58.2	71.2	84.1	97.0	110.0
2.48	58.6	71.6	84.6	97.6	110.6
2.49	58.9	72.0	85.1	98.2	111.2
2.50	59.2	72.4	85.6	98.7	111.9

Head *H*, feet	Length of weir *L*, feet			
	6.0	7.0	8.0	9.0
2.51	72.8	86.0	99.3	112.5
2.52	73.2	86.5	99.9	113.2
2.53	73.6	87.0	100.4	113.8
2.54	74.0	87.5	101.0	114.5
2.55	74.4	88.0	101.6	115.1
2.56	74.9	88.5	102.1	115.8
2.57	75.3	89.0	102.7	116.4
2.58	75.7	89.5	103.3	117.1
2.59	76.1	90.0	103.8	117.7
2.60	76.5	90.5	104.4	118.4
2.61	76.9	91.0	105.0	119.0
2.62	77.3	91.5	105.6	119.7
2.63	77.7	92.0	106.2	120.4
2.64	78.2	92.4	106.7	121.0
2.65	78.5	92.9	107.2	121.6
2.66	79.0	93.4	107.9	122.3
2.67	79.4	93.9	108.5	123.0
2.68	79.8	94.4	109.0	123.7
2.69	80.2	94.9	109.6	124.3
2.70	80.7	95.4	110.2	125.0
2.71	81.1	95.9	110.8	125.7
2.72	81.5	96.4	111.4	126.3
2.73	81.9	96.9	112.0	127.0
2.74	82.3	97.4	112.5	127.7
2.75	82.8	98.0	113.1	128.3
2.76	83.2	98.5	113.7	129.0
2.77	83.6	99.0	114.3	129.7
2.78	84.0	99.5	114.9	130.3
2.79	84.5	100.0	115.5	131.0
2.80	84.9	100.5	116.1	131.7
2.81	85.3	101.0	116.7	132.4
2.82	85.7	101.5	117.3	133.0
2.83	86.1	102.0	117.9	133.7
2.84	86.6	102.5	118.5	134.4
2.85	87.0	103.0	119.0	135.1
2.86	87.4	103.5	119.6	135.7
2.87	87.9	104.0	120.2	136.4
2.88	88.3	104.6	120.8	137.1
2.89	88.7	105.1	121.4	137.8
2.90	89.1	105.6	122.0	138.5
2.91	89.6	106.1	122.6	139.1
2.92	90.0	106.6	123.2	139.8
2.93	90.4	107.1	123.8	140.5
2.94	90.9	107.6	124.4	141.2
2.95	91.3	108.1	125.0	141.9
2.96	91.7	108.7	125.6	142.6
2.97	92.1	109.2	126.2	143.3
2.98	92.6	109.7	126.8	144.0
2.99	93.0	110.2	127.4	144.7
3.00	93.4	110.7	128.0	145.3

Table 4. Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from formula $Q=3.33(L-0.2H)H^{3/2}$ (Cont'd).

Head H, feet	Length of weir L, feet 7.0	8.0	9.0	Head H, feet	Length of weir L, feet 8.0	9.0	Head H, feet	Length of weir L, feet 9.0
3.01	111.3	128.6	146.0	3.51	159.8	181.7	4.01	219.2
3.02	111.7	129.2	146.7	3.52	160.4	182.4	4.02	220.0
3.03	112.3	129.9	147.4	3.53	161.1	183.2	4.03	220.8
3.04	112.8	130.5	148.1	3.54	161.7	183.9	4.04	221.5
3.05	113.3	131.1	148.8	3.55	162.4	184.6	4.05	222.3
3.06	113.9	131.7	149.5	3.56	163.0	185.4	4.06	223.1
3.07	114.4	132.3	150.2	3.57	163.7	186.1	4.07	223.9
3.08	114.9	132.9	150.9	3.58	164.3	186.9	4.08	224.6
3.09	115.4	133.5	151.6	3.59	164.9	187.6	4.09	225.3
3.10	116.0	134.1	152.3	3.60	165.6	188.3	4.10	226.1
3.11	116.5	134.7	153.0	3.61	166.2	189.1	4.11	226.9
3.12	117.0	135.4	153.7	3.62	166.9	189.8	4.12	227.7
3.13	117.5	136.0	154.4	3.63	167.5	190.6	4.13	228.5
3.14	118.1	136.6	155.1	3.64	168.2	191.3	4.14	229.2
3.15	118.6	137.2	155.8	3.65	168.8	192.0	4.15	230.0
3.16	119.1	137.8	156.5	3.66	169.5	192.8	4.16	230.8
3.17	119.6	138.4	157.2	3.67	170.1	193.5	4.17	231.6
3.18	120.2	139.1	157.9	3.68	170.8	194.3	4.18	232.3
3.19	120.7	139.7	158.6	3.69	171.4	195.0	4.19	233.1
3.20	121.2	140.3	159.4	3.70	172.1	195.8	4.20	233.9
3.21	121.8	140.9	160.1	3.71	172.7	196.5	4.21	234.7
3.22	122.3	141.5	160.8	3.72	173.4	197.3	4.22	235.4
3.23	122.8	142.2	161.5	3.73	174.0	198.0	4.23	236.2
3.24	123.4	142.8	162.2	3.74	174.7	198.8	4.24	237.0
3.25	123.9	143.4	162.9	3.75	175.3	199.5	4.25	237.8
3.26	124.4	144.0	163.6	3.76	176.0	200.3	4.26	238.6
3.27	125.0	144.6	164.3	3.77	176.6	201.0	4.27	239.3
3.28	125.5	145.3	165.1	3.78	177.3	201.8	4.28	240.1
3.29	126.0	145.9	165.8	3.79	177.9	202.5	4.29	240.9
3.30	126.6	146.5	166.5	3.80	178.6	203.3	4.30	241.7
3.31	127.1	147.2	167.2	3.81	179.2	204.0	4.31	242.5
3.32	127.6	147.8	167.9	3.82	179.9	204.8	4.32	243.3
3.33	128.2	148.4	168.6	3.83	180.6	205.5	4.33	244.1
3.34	128.7	149.0	169.4	3.84	181.2	206.3	4.34	244.8
3.35	129.2	149.7	170.1	3.85	181.9	207.0	4.35	245.7
3.36	129.8	150.3	170.8	3.86	182.5	207.8	4.36	246.4
3.37	130.3	150.9	171.5	3.87	183.2	208.5	4.37	247.2
3.38	130.9	151.6	172.2	3.88	183.9	209.3	4.38	248.0
3.39	131.4	152.2	173.0	3.89	184.5	210.1	4.39	248.8
3.40	131.9	152.8	173.7	3.90	185.2	210.8	4.40	249.6
3.41	132.5	153.5	174.4	3.91	185.8	211.6	4.41	250.4
3.42	133.0	154.1	175.1	3.92	186.7	212.6	4.42	251.1
3.43	133.6	154.7	175.9	3.93	187.2	213.1	4.43	251.9
3.44	134.1	155.4	176.6	3.94	187.8	213.9	4.44	252.7
3.45	134.6	156.0	177.3	3.95	188.5	214.6	4.45	253.5
3.46	135.2	156.6	178.1	3.96	189.1	215.4	4.46	254.3
3.47	135.7	157.3	178.8	3.97	189.8	216.2	4.47	255.1
3.48	136.3	157.9	179.5	3.98	190.5	216.9	4.48	255.9
3.49	136.8	158.5	180.2	3.99	191.1	217.7	4.49	256.7
3.50	137.4	159.2	181.0	4.00	191.8	218.4	4.50	257.5

Table 5. - Discharge Of Standard Suppressed Rectangular Weirs In Second-Feet Computed From Formula $Q = 3.33\ LH^{3/2}$

Head-H Feet	Length of weir, L, in Feet 0.5	1.0	1.5	2.0	3.0	4.0	5.0
.01	.002	.003	.005	.007	.010	.013	.017
.02	.005	.010	.014	.019	.028	.038	.047
.03	.009	.017	.026	.035	.052	.069	.087
.04	.013	.027	.040	.053	.080	.106	.133
.05	.019	.037	.056	.074	.112	.149	.186
.06	.025	.049	.073	.098	.147	.196	.245
.07	.031	.062	.093	.123	.185	.247	.309
.08	.038	.075	.113	.151	.226	.301	.377
.09	.045	.090	.135	.180	.270	.360	.450
.10	.053	.105	.158	.211	.316	.421	.527
.11	.061	.122	.182	.243	.365	.486	.608
.12	.069	.138	.208	.277	.415	.554	.692
.13	.078	.156	.234	.312	.468	.624	.781
.14	.087	.174	.262	.349	.523	.698	.872
.15	.097	.194	.290	.387	.581	.774	.968
.16	.107	.213	.320	.426	.639	.852	1.07
.17	.116	.233	.350	.467	.700	.932	1.17
.18		.254	.382	.509	.763	1.02	1.27
.19		.276	.414	.552	.827	1.10	1.38
.20		.298	.447	.596	.893	1.19	1.49
.21		.321	.481	.641	.962	1.28	1.60
.22		.344	.515	.687	1.03	1.37	1.72
.23		.367	.551	.735	1.10	1.47	1.84
.24		.392	.587	.783	1.18	1.57	1.96
.25		.416	.624	.832	1.25	1.67	2.08
.26		.442	.662	.883	1.33	1.77	2.21
.27		.467	.701	.934	1.40	1.87	2.34
.28		.493	.740	.987	1.48	1.97	2.47
.29		.520	.780	1.04	1.56	2.08	2.60
.30		.547	.821	1.09	1.64	2.19	2.74
.31		.575	.862	1.15	1.72	2.30	2.87
.32		.603	.904	1.21	1.81	2.41	3.01
.33		.631	.947	1.26	1.89	2.53	3.16
.34		.660	.990	1.32	1.98	2.64	3.30
.35			1.03	1.38	2.07	2.76	3.45
.36			1.08	1.44	2.16	2.88	3.60
.37			1.12	1.50	2.25	3.00	3.75
.38			1.17	1.56	2.34	3.12	3.90
.39			1.22	1.62	2.43	3.24	4.06
.40			1.26	1.68	2.53	3.37	4.21
.41			1.31	1.75	2.62	3.50	4.37
.42			1.36	1.81	2.72	3.63	4.53
.43			1.41	1.88	2.82	3.76	4.70
.44			1.46	1.94	2.92	3.89	4.85

Table 5. - Discharge Of Standard Suppressed Rectangular Weirs In Second-Feet, Computed From Formula $Q = 3.33 LH^{3/2}$ --Continued

Head-H Feet	Length of weir, L, in Feet						
	0.5	1.0	1.5	2.0	3.0	4.0	5.0
.45			1.51	2.01	3.02	4.02	5.03
.46			1.56	2.08	3.12	4.16	5.19
.47			1.61	2.15	3.22	4.29	5.37
.48			1.66	2.22	3.32	4.43	5.54
.49			1.71	2.28	3.43	4.57	5.71
.50			1.77	2.35	3.53	4.71	5.89
.51				2.43	3.64	4.85	6.06
.52				2.50	3.75	5.00	6.24
.53				2.57	3.85	5.14	6.43
.54				2.64	3.96	5.29	6.61
.55				2.72	4.08	5.43	6.79
.56				2.79	4.19	5.58	6.98
.57				2.87	4.30	5.73	7.17
.58				2.94	4.41	5.88	7.35
.59				3.02	4.53	6.04	7.55
.60				3.10	4.64	6.19	7.74
.61				3.17	4.76	6.35	7.93
.62				3.25	4.88	6.50	8.13
.63				3.33	5.00	6.66	8.33
.64				3.41	5.12	6.82	8.53
.65				3.49	5.24	6.98	8.73
.66				3.57	5.36	7.14	8.93
.67				3.65	5.48	7.31	9.13
.68					5.60	7.47	9.34
.69					5.73	7.63	9.54
.70					5.85	7.80	9.75
.71					5.98	7.97	9.96
.72					6.10	8.14	10.17
.73					6.23	8.31	10.39
.74					6.36	8.48	10.60
.75					6.49	8.65	10.81
.76					6.62	8.83	11.03
.77					6.75	9.00	11.25
.78					6.88	9.18	11.47
.79					7.02	9.35	11.69
.80					7.15	9.53	11.91
.81					7.28	9.71	12.14
.82					7.42	9.89	12.36
.83					7.55	10.07	12.59
.84					7.69	10.26	12.82
.85					7.83	10.44	13.05
.86					7.97	10.62	13.28
.87					8.11	10.81	13.51
.88					8.25	11.00	13.75
.89					8.39	11.18	13.98
.90					8.53	11.37	14.22

Table 5. — Discharge Of Standard Suppressed Rectangular Weirs In Second-Feet, Computed From Formula $Q = 3.33 LH^{3/2}$ —Continued

Head-H	Length of weir, L, in Feet						
Feet	0.5	1.0	1.5	2.0	3.0	4.0	5.0
.91					8.67	11.56	14.45
.92					8.82	11.75	14.69
.93					8.96	11.95	14.93

Table 5. - Discharge of [illegible]

Feet Computed From Formula [illegible]

Head-H Feet	Length of weir, L, in feet: 3.0	4.0	5.0	Head-H, Ft.	Length of [illegible]: [illegible]	[illegible]	[illegible]
.94	9.10	12.14	15.17	1.42	16.[illegible]	22.[illegible]	[illegible]
.95	9.25	12.33	15.42	1.43	17.[illegible]	22.73	[illegible]
.96	9.40	12.53	15.66	1.44	17.[illegible]	23.[illegible]	[illegible]
.97	9.54	12.73	15.91	1.45	17.[illegible]	23.25	[illegible]
.98	9.69	12.92	16.15	1.46	17.62	23.50	[illegible]
.99	9.84	13.12	16.40	1.47	17.[illegible]	23.74	[illegible]
1.00	9.99	13.32	16.65	1.48	17.99	23.98	[illegible]
1.01	10.14	13.52	16.90	1.49	18.17	24.23	[illegible]
1.02	10.29	13.72	17.15	1.50	18.35	24.47	[illegible]
1.03	10.44	13.92	17.41	1.51		24.72	[illegible]
1.04	10.60	14.13	17.66	1.52		24.96	[illegible]
1.05	10.75	14.33	17.91	1.53		25.21	[illegible]
1.06	10.90	14.54	18.17	1.54		25.46	[illegible]
1.07	11.06	14.74	18.43	1.55		25.70	[illegible]
1.08	11.21	14.95	18.69	1.56		25.95	[illegible]
1.09	11.37	15.16	18.95	1.57		26.[illegible]	[illegible]
1.10	11.53	15.37	19.21	1.58		26.45	[illegible]
1.11	11.68	15.58	19.47	1.59		26.72	[illegible]
1.12	11.84	15.79	19.74	1.60		26.96	[illegible]
1.13	12.00	16.00	20.00	1.61		27.21	[illegible]
1.14	12.16	16.21	20.27	1.62		27.47	[illegible]
1.15	12.32	16.43	20.53	1.63		27.72	[illegible]
1.16	12.48	16.64	20.80	1.64		27.[illegible]	[illegible]
1.17	12.64	16.86	21.07	1.65		[illegible]	[illegible]
1.18	12.81	17.07	21.34	1.66		[illegible]	[illegible]
1.19	12.97	17.29	21.61	1.67		[illegible]	[illegible]
1.20	13.13	17.51	21.89	1.68		29.[illegible]	[illegible]
1.21	13.30	17.73	22.16	1.69		[illegible]	[illegible]
1.22	13.46	17.95	22.44	1.70		[illegible]	[illegible]
1.23	13.63	18.17	22.71	1.71		[illegible]	[illegible]
1.24	13.79	18.39	22.99	1.72		[illegible]	[illegible]
1.25	13.96	18.62	23.27	1.73		[illegible]	[illegible]
1.26	14.13	18.84	23.55	[illegible]		[illegible]	[illegible]
1.27	14.30	19.06	[illegible]	[illegible]		[illegible]	[illegible]
1.28	14.47	19.29	24.11	[illegible]		[illegible]	[illegible]
1.29	14.64	19.52	24.40	1.77		[illegible]	[illegible]
1.30	14.81	19.74	24.68	1.78		[illegible]	[illegible]
1.31	14.98	19.97	24.97	1.79		[illegible]	[illegible]
1.32	15.15	20.20	25.23	[illegible]		[illegible]	[illegible]
1.33	15.32	20.43	25.56	[illegible]		[illegible]	[illegible]
1.34	15.49	20.66	[illegible]	[illegible]		[illegible]	[illegible]
1.35	15.67	20.89	[illegible]	[illegible]		[illegible]	[illegible]
1.36	15.84	21.13	[illegible]	[illegible]		[illegible]	[illegible]
1.37	16.02	21.36	[illegible]	[illegible]		[illegible]	[illegible]
1.38	16.20	21.59	[illegible]	[illegible]		[illegible]	[illegible]
1.39	16.37	21.83	27.29	[illegible]		[illegible]	[illegible]
1.40	16.55	22.06	[illegible]	[illegible]		[illegible]	[illegible]
1.41	16.73	22.30	[illegible]	[illegible]		[illegible]	[illegible]

Table 5. – Discharge Of Standard Suppressed Rectangular Weirs In Second-Feet, Computed From Formula $Q = 3.33 LH^{3/2}$ ---Continued.

Head-H	Length of weir, L, in Feet						
Feet	0.5	1.0	1.5	2.0	3.0	4.0	5.0
1.83						32.98	41.22
1.84						33.25	41.56
1.85						33.52	41.90
1.86						33.79	42.24
1.87						34.06	42.58
1.88						34.34	42.92
1.89						34.61	43.26
1.90						34.89	43.61
1.91						35.16	43.95
1.92						35.44	44.30
1.93						35.71	44.64
1.94						35.99	44.99
1.95						36.27	45.34
1.96						36.55	45.69
1.97						36.83	46.04
1.98						37.11	46.39
1.99						37.39	46.74
2.00						37.68	47.10

Table 6. Discharge of standard Cipolletti weirs in second-feet. Values below and to the left of heavy line determined experimentally; others computed from formula $Q=3.367LH^{3/2}$

Head H, feet	Length of weir L, feet: 0.5	1.0	1.5	2.0	3.0	4.0	5.0
0.01	0.002	0.003	0.005	0.007	0.010	0.013	0.017
.02	.005	.010	.014	.019	.029	.038	.048
.03	.009	.018	.026	.035	.053	.070	.087
.04	.013	.027	.040	.054	.081	.108	.135
.05	.019	.038	.057	.075	.113	.151	.188
.06	.025	.050	.074	.099	.148	.198	.247
.07	.031	.062	.093	.125	.187	.249	.312
.08	.038	.076	.114	.152	.229	.305	.381
.09	.045	.091	.136	.182	.273	.364	.455
.10	.053	.107	.160	.213	.319	.426	.532
.11	.061	.123	.184	.246	.369	.491	.614
.12	.070	.140	.210	.280	.420	.560	.700
.13	.079	.158	.237	.316	.473	.631	.789
.14	.088	.176	.265	.353	.529	.705	.882
.15	.098	.196	.293	.391	.587	.782	.978
.16	.108	.216	.323	.431	.646	.862	1.08
.17	.118	.236	.354	.472	.708	.944	1.18
.18	.129	.257	.386	.514	.771	1.03	1.28
.19	.139	.279	.418	.558	.837	1.12	1.39
.20	.151	.301	.452	.602	.903	1.20	1.51
.21	.162	.324	.486	.648	.972	1.30	1.62
.22	.174	.347	.521	.695	1.04	1.39	1.74
.23	.186	.371	.557	.743	1.11	1.48	1.86
.24	.200	.396	.594	.792	1.19	1.58	1.98
.25	.211	.421	.631	.842	1.26	1.68	2.10
.26		.446	.669	.892	1.34	1.78	2.23
.27		.472	.709	.945	1.42	1.89	2.36
.28		.499	.748	.998	1.50	2.00	2.49
.29		.526	.789	1.05	1.58	2.10	2.63
.30		.553	.830	1.11	1.66	2.21	2.77
.31		.581	.872	1.16	1.74	2.32	2.90
.32		.609	.914	1.22	1.83	2.44	3.05
.33		.638	.957	1.28	1.92	2.55	3.19
.34		.667	1.00	1.34	2.00	2.67	3.34
.35		.697	1.05	1.39	2.09	2.79	3.49
.36		.727	1.09	1.45	2.18	2.91	3.64
.37		.758	1.14	1.52	2.27	3.03	3.79
.38		.789	1.18	1.58	2.37	3.16	3.94
.39		.820	1.23	1.64	2.46	3.28	4.10
.40		.852	1.28	1.70	2.56	3.41	4.26
.41		.884	1.33	1.77	2.65	3.54	4.42
.42		.916	1.38	1.83	2.75	3.66	4.58
.43		.949	1.42	1.90	2.85	3.80	4.75
.44		.983	1.47	1.96	2.95	3.93	4.91
.45		1.02	1.52	2.03	3.05	4.06	5.08
.46		1.05	1.58	2.10	3.15	4.20	5.25
.47		1.08	1.63	2.17	3.25	4.34	5.42
.48		1.12	1.68	2.24	3.36	4.48	5.60
.49		1.16	1.73	2.31	3.46	4.62	5.77
.50		1.19	1.78	2.38	3.57	4.76	5.95

Head H, feet	Length of weir L, feet: 1.5	2.0
0.51	1.84	2.45
.52	1.89	2.52
.53	1.95	2.60
.54	2.00	2.67
.55	2.06	2.75
.56	2.12	2.82
.57	2.17	2.90
.58	2.23	2.97
.59	2.29	3.05
.60	2.35	3.13
.61	2.41	3.21
.62	2.46	3.29
.63	2.52	3.37
.64	2.59	3.45
.65	2.65	3.53
.66	2.71	3.61
.67	2.77	3.69
.68	2.83	3.81
.69	2.89	3.90
.70	2.96	3.98
.71	3.02	4.06
.72	3.08	4.15
.73	3.15	4.21
.74	3.22	4.33
.75	3.28	4.42
.76		4.51
.77		4.60
.78		4.69
.79		4.78
.80		4.87
.81		4.96
.82		5.05
.83		5.14
.84		5.21
.85		5.31
.86		5.41
.87		5.51
.88		5.61
.89		5.71
.90		5.81
.91		5.91
.92		6.01
.93		6.14
.94		6.25
.95		6.36
.96		6.47
.97		6.58
.98		6.69
.99		6.80
1.00		6.91

Table 6. Discharge of standard Cipolletti weirs in second-feet. Values below and to the left of heavy line determined experimentally; others computed from the formula $Q=3.367LH^{3/2}$ (Cont'd).

Head *H*, feet	Length of weir *L*, feet			Head *H*, feet	Length of weir *L*, feet			Head *H*, feet	Length of weir *L*, feet	
	3.0	4.0	5.0		3.0	4.0	5.0		4.0	5.0
0.51	3.68	4.90	6.13	1.01	10.5	13.7	17.1	1.51	25.0	31.2
.52	3.79	5.05	6.31	1.02	10.6	13.9	17.3	1.52	25.2	31.5
.53	3.90	5.20	6.50	1.03	10.8	14.1	17.6	1.53	25.5	31.8
.54	4.01	5.34	6.68	1.04	10.9	14.3	17.9	1.54	25.7	32.2
.55	4.12	5.49	6.87	1.05	11.1	14.5	18.1	1.55	26.0	32.5
.56	4.23	5.64	7.05	1.06	11.3	14.7	18.4	1.56	26.2	32.8
.57	4.35	5.80	7.24	1.07	11.4	14.9	18.6	1.57	26.5	33.1
.58	4.46	5.95	7.44	1.08	11.6	15.1	18.9	1.58	26.7	33.4
.59	4.58	6.10	7.63	1.09	11.7	15.3	19.2	1.59	27.0	33.8
.60	4.69	6.26	7.82	1.10	11.9	15.5	19.4	1.60	27.3	34.1
.61	4.81	6.42	8.02	1.11	12.1	15.8	19.7	1.61	27.5	34.4
.62	4.93	6.57	8.22	1.12	12.2	16.0	20.0	1.62	27.8	34.7
.63	5.05	6.73	8.42	1.13	12.4	16.2	20.2	1.63	28.0	35.0
.64	5.17	6.90	8.62	1.14	12.5	16.4	20.5	1.64	28.3	35.4
.65	5.29	7.06	8.82	1.15	12.7	16.6	20.8	1.65	28.5	35.7
.66	5.42	7.22	9.03	1.16	12.9	16.8	21.0	1.66	28.8	36.0
.67	5.54	7.38	9.23	1.17	13.0	17.0	21.3	1.67	29.1	36.3
.68	5.66	7.55	9.44	1.18	13.2	17.3	21.6	1.68	29.3	36.7
.69	5.79	7.72	9.65	1.19	13.4	17.5	21.9	1.69	29.6	37.0
.70	5.92	7.89	9.86	1.20	13.6	17.7	22.1	1.70	29.9	37.3
.71	6.04	8.06	10.1	1.21	13.7	17.9	22.4	1.71	30.1	37.6
.72	6.17	8.23	10.3	1.22	13.9	18.1	22.7	1.72	30.4	38.0
.73	6.30	8.40	10.5	1.23	14.1	18.4	23.0	1.73	30.6	38.3
.74	6.43	8.57	10.7	1.24	14.3	18.6	23.2	1.74	30.9	38.6
.75	6.56	8.75	10.9	1.25	14.4	18.8	23.5	1.75	31.1	39.0
.76	6.69	8.92	11.2	1.26	14.6	19.0	23.8	1.76	31.4	39.3
.77	6.82	9.10	11.4	1.27	14.8	19.3	24.1	1.77	31.7	39.6
.78	6.96	9.28	11.6	1.28	15.0	19.5	24.4	1.78	32.0	40.0
.79	7.09	9.46	11.8	1.29	15.2	19.7	24.7	1.79	32.3	40.3
.80	7.23	9.64	12.0	1.30	15.4	20.0	25.0	1.80	32.5	40.7
.81	7.36	9.82	12.3	1.31	15.5	20.2	25.2	1.81	32.8	41.0
.82	7.50	10.0	12.5	1.32	15.7	20.4	25.5	1.82	33.1	41.3
.83	7.64	10.2	12.7	1.33	15.9	20.7	25.8	1.83	33.3	41.7
.84	7.78	10.4	13.0	1.34	16.1	20.9	26.1	1.84	33.6	42.0
.85	7.92	10.6	13.2	1.35	16.2	21.1	26.4	1.85	33.9	42.4
.86	8.06	10.7	13.4	1.36	16.4	21.4	26.7	1.86	34.2	42.7
.87	8.20	10.9	13.7	1.37	16.6	21.6	27.0	1.87	34.4	43.0
.88	8.34	11.1	13.9	1.38	16.8	21.8	27.3	1.88	34.7	43.4
.89	8.48	11.3	14.1	1.39	17.0	22.1	27.6	1.89	35.0	43.7
.90	8.62	11.5	14.4	1.40	17.2	22.3	27.9	1.90	35.3	44.1
.91	8.77	11.7	14.6	1.41	17.4	22.5	28.2	1.91	35.6	44.4
.92	8.91	11.9	14.9	1.42	17.6	22.8	28.5	1.92	35.8	44.8
.93	9.06	12.1	15.1	1.43	17.8	23.0	28.8	1.93	36.1	45.1
.94	9.20	12.3	15.3	1.44	18.0	23.3	29.1	1.94	36.4	45.5
.95	9.35	12.5	15.6	1.45	18.2	23.5	29.4	1.95	36.7	45.8
.96	9.50	12.7	15.8	1.46	18.3	23.8	29.7	1.96	37.0	46.2
.97	9.65	12.9	16.1	1.47	18.5	24.0	30.0	1.97	37.2	46.5
.98	9.80	13.1	16.3	1.48	18.7	24.2	30.3	1.98	37.5	46.9
.99	9.95	13.3	16.6	1.49	18.9	24.5	30.6	1.99	37.8	47.3
1.00	10.1	13.5	16.8	1.50	19.1	24.7	30.9	2.00	38.1	47.6

Table 5. Discharge of standard Cipolletti weirs in second-feet. Values computed from the formula $Q=3.367LH^{3/2}$ (Cont'd).

Depth on Crest (ft.)	Length of weir (ft.)				Depth on Crest (ft.)	Length of weir (ft.)			
	6.00	7.00	8.00	9.00		6.00	7.00	8.00	9.00
0.01	.02	.02	.03	.03	.41	530	619	707	795
.02	.06	.07	.08	.09	.42	550	641	733	825
.03	.11	.12	.14	.16	.43	570	665	759	854
.04	.16	.19	.22	.24	.44	590	688	786	884
.05	.23	.26	.30	.34	.45	610	711	813	915
.06	.30	.35	.40	.45	.46	630	735	840	945
.07	.37	.44	.50	.56	.47	651	759	868	976
.08	.46	.53	.61	.69	.48	672	784	896	1 008
.09	.55	.64	.73	.82	.49	693	808	924	1 039
.10	.64	.75	.85	.96	.50	714	833	952	1 071
.11	.74	.86	.98	111	0.51	736	858	981	1 104
.12	.84	.98	112	126	.52	757	884	1 010	1 136
.13	.95	110	126	142	.53	779	909	1 039	1 169
.14	106	123	141	159	.54	802	935	1 069	1 202
.15	117	137	156	176	.55	824	961	1 099	1 236
.16	129	151	172	194	.56	847	988	1 129	1 270
.17	142	165	189	212	.57	869	1 014	1 159	1 304
.18	154	180	206	231	.58	892	1 041	1 190	1 338
.19	167	195	223	251	.59	915	1 068	1 221	1 373
.20	181	211	241	271	.60	939	1 095	1 252	1 408
.21	194	227	259	292	.61	962	1 123	1 283	1 444
.22	208	243	278	313	.62	986	1 151	1 315	1 479
.23	223	260	297	334	.63	1 010	1 178	1 347	1 515
.24	238	277	317	356	.64	1 034	1 207	1 379	1 551
.25	253	295	337	379	.65	1 059	1 235	1 411	1 588
.26	268	312	357	402	.66	1 083	1 264	1 444	1 625
.27	283	331	378	425	.67	1 108	1 292	1 477	1 662
.28	299	349	399	449	.68	1 133	1 321	1 510	1 699
.29	315	368	421	473	.69	1 158	1 351	1 544	1 737
.30	332	387	443	498	.70	1 183	1 380	1 577	1 775
.31	349	407	465	523	.71	1 208	1 410	1 611	1 813
.32	366	427	488	548	.72	1 234	1 440	1 645	1 851
.33	383	447	511	574	.73	1 260	1 470	1 680	1 890
.34	400	467	534	601	.74	1 286	1 500	1 715	1 929
.35	418	488	558	627	.75	1 312	1 531	1 749	1 968
.36	436	509	582	654	.76	1 338	1 561	1 784	2 008
.37	455	530	606	682	.77	1 363	1 592	1 820	2 047
.38	473	552	631	710	.78	1 392	1 623	1 855	2 087
.39	492	574	656	738	.79	1 418	1 655	1 891	2 128
.40	511	596	681	767	.80	1 445	1 686	1 927	2 168

Table 6. Discharge of standard Cipolletti weirs in second-feet. Values computed from the formula $Q=3.367LH^{3/2}$ (Cont'd).

Depth on Crest (ft.)	Length of Weir (ft.)				Depth on Crest (ft.)	Length of Weir (ft.)			
	6.00	7.00	8.00	9.00		6.00	7.00	8.00	9.00
.81	14.73	17.18	19.63	22.09	1.21	26.90	31.37	35.85	40.33
.82	15.00	17.50	20.00	22.50	1.22	27.22	31.76	36.29	40.83
.83	15.27	17.82	20.37	22.91	1.23	27.56	32.15	36.74	41.33
.84	15.55	18.14	20.74	23.33	1.24	27.89	32.54	37.10	41.84
.85	15.83	18.47	21.11	23.74	1.25	28.23	32.94	37.64	42.35
[illegible]	16.11	18.80	21.48	24.17	[illegible]	28.57	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	19.12	[illegible]	24.60	[illegible]	28.91	[illegible]	[illegible]	43.37
[illegible]	[illegible]	19.45	[illegible]	25.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	19.79	[illegible]	25.44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	20.13	[illegible]	25.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 6. Discharge of standard Cipolletti weirs in second-feet. Values computed from the formula $Q=3.367LH^{3/2}$ (Cont'd).

Depth on Crest (ft.)	Length of Weir (ft.) 6.00	7.00	8.00	9.00	Depth on Crest (ft.)	Length of Weir (ft.) 6.00	7.00	8.00	9.00
1.61	4 127	4 814	5 502	6 190	2.6	8 469	9 880	11 291	12 703
1.62	4 165	4 859	5 553	6 248	2.7	8 962	10 455	11 949	13 443
1.63	4 204	4 904	5 605	6 305	2.8	9 464	11 042	12 619	14 196
1.64	4 242	4 950	5 657	6 364	2.9	9 976	11 638	13 301	14 964
1.65	4 281	4 995	5 708	6 422	3.0	10 496	12 246	13 995	15 744
1.66	4 320	5 040	5 760	6 480	3.1	11 026	12 863	14 700	16 538
1.67	4 359	5 086	5 813	6 539	3.2	11 563	13 490	15 418	17 345
1.68	4 399	5 132	5 865	6 598	3.3	12 110	14 128	16 146	18 164
1.69	4 438	5 178	5 917	6 657	3.4	12 664	14 775	16 885	18 996
1.70	4 477	5 224	5 970	6 716	3.5	13 227	15 431	17 636	19 840
1.71	4 517	5 270	6 023	6 775	3.6	13 799	16 099	18 397	20 698
1.72	4 557	5 316	6 076	6 835	3.7	14 377	16 773	19 169	21 565
1.73	4 596	5 362	6 129	6 895	3.8	14 965	17 457	19 951	22 445
1.74	4 636	5 409	6 182	6 954	3.9	15 553	18 151	20 744	23 337
1.75	4 676	5 456	6 235	7 015	4.0	16 160	18 853	21 547	24 240
1.76	4 716	5 503	6 289	7 075	4.1	16 770	19 565	22 360	25 156
1.77	4 757	5 550	6 342	7 135	4.2	17 387	20 285	23 182	26 081
1.78	4 797	5 597	6 396	7 196	4.3	18 012	21 014	24 016	27 018
1.79	4 838	5 644	6 450	7 256	4.4	18 644	21 751	24 858	27 965
1.80	4 878	5 691	6 504	7 317	4.5	19 283	22 497	25 710	28 924
1.81	4 919	5 739	6 559	7 378	4.6	19 929	23 251	26 572	29 894
1.82	4 960	5 786	6 613	7 440	4.7	20 583	24 013	27 443	30 874
1.83	5 001	5 834	6 668	7 501	4.8	21 243	24 783	28 324	31 864
1.84	5 042	5 882	6 722	7 563	4.9	21 910	25 562	29 214	32 865
1.85	5 083	5 930	6 777	7 624	5.0	22 584	26 348	30 112	33 876
1.86	5 124	5 978	6 832	7 686	5.5	26 055	30 398	34 740	39 083
1.87	5 166	6 026	6 887	7 748	6.0	29 688	34 636	39 584	44 532
1.88	5 207	6 075	6 943	7 810	6.5	33 475	39 054	44 633	50 212
1.89	5 249	6 123	6 998	7 873	7.0	37 411	43 646	49 881	56 116
1.90	5 290	6 172	7 054	7 935	7.5	41 490	48 405	55 320	62 235
1.91	5 332	6 221	7 110	7 998	8.0	45 707	53 325	60 943	68 561
1.92	5 374	6 270	7 165	8 061	8.5	50 059	58 402	66 745	75 088
1.93	5 416	6 319	7 221	8 124	9.0	54 540	63 630	72 720	81 810
1.94	5 458	6 368	7 278	8 187	9.5	59 148	69 006	78 863	88 721
1.95	5 500	6 417	7 334	8 251	10	63 878	74 524	85 171	95 817
1.96	5 543	6 467	7 390	8 314	11	73 696	85 978	98 260	110 543
1.97	5 585	6 516	7 447	8 378	12	83 970	97 965	111 960	125 955
1.98	5 628	6 566	7 504	8 442	13	94 682	110 462	120 242	142 023
1.99	5 671	6 616	7 561	8 506	14	105 814	123 450	141 085	158 721
2.00	5 713	6 666	7 618	8 570	15	117 351	136 910	156 469	176 027
2.1	6 147	7 172	8 196	9 221	16	129 280	150 827	172 373	193 920
2.2	6 592	7 690	8 789	9 887	17	141 557	165 186	188 783	212 381
2.3	7 046	8 220	9 395	10 569	18	154 262	179 973	205 683	231 394
2.4	7 510	8 762	10 014	11 266	19	167 295	195 177	223 059	250 943
2.5	7 985	9 316	10 646	11 977	20	180 674	210 787	240 899	271 011

160

Table 8. Coefficients C to be applied to discharge taken from tables 4, 5, or 6 for a head, H, to obtain the discharge of the same weir when a velocity of approach, V, exists; computed from the formula $C = \frac{Q'}{Q} = \frac{D^{3/2}}{H^{3/2}}$.

r	h	$h^{3/2}$	H 0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
0.4	0.0025	0.0002	1.014	1.007	1.004	1.004	1.004	1.002	1.002	1.002	1.001	1.001	1.001	1.001
.5	.0039	.0003	1.027	1.013	1.009	1.007	1.005	1.004	1.003	1.002	1.002	1.002	1.001	1.001
.6	.0056	[illegible]	1.037	1.019	1.013	1.009	1.006	1.005	1.004	1.003	1.003	1.002	1.002	1.002
.7	.0076	.0007	1.050	1.026	1.017	1.013	1.011	1.007	1.006	1.004	1.004	1.003	1.003	1.002
.8	.0099	.0010	1.064	1.033	1.022	1.016	1.014	1.009	1.007	1.005	1.005	1.004	1.003	1.003
.9	[illegible]	.0014	1.082	1.042	1.028	1.021	1.018	1.012	1.009	1.007	1.006	1.005	1.005	1.004
1.0	.0155	.0019	1.099	1.051	1.034	1.027	1.022	1.015	1.011	1.009	1.007	1.006	1.005	1.005
1.1	.0188	.0025	1.122	1.062	1.041	1.031	[illegible]	1.017	1.013	1.011	1.009	1.008	1.007	1.006
1.2	.0224	.0033	1.141	1.072	1.049	1.037	1.031	1.021	1.016	1.013	1.011	1.009	1.008	1.007
1.3	.0263	.0041	1.163	1.084	1.057	1.043	[illegible]	1.024	1.018	1.015	1.012	1.011	1.009	1.008
1.4	.0305	.0051	[illegible]	1.096	1.066	1.050	1.041	1.028	1.021	1.017	1.014	1.012	1.011	1.010
1.5	.0350	[illegible]	1.208	[illegible]	1.075	1.057	1.047	1.032	1.024	1.019	1.016	1.014	1.012	1.011
1.6	.0398	[illegible]	1.225	1.122	1.084	1.065	1.052	1.035	1.027	1.022	1.018	1.016	1.014	1.012
1.7	.0448	[illegible]	1.254	1.135	[illegible]	1.071	[illegible]	[illegible]	1.031	1.025	1.021	[illegible]	1.016	1.014
1.8	.0504	.0111	1.277	1.149	1.104	[illegible]	1.065	[illegible]	1.034	1.027	1.023	1.020	1.017	1.016
1.9	.0561	[illegible]	[illegible]	1.165	1.115	[illegible]	1.072	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.017
2.0	.0622	[illegible]	1.335	1.181	[illegible]	1.097	1.079	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.019
2.1	[illegible]	.0179	1.363	1.197	1.127	[illegible]	1.087	[illegible]	[illegible]	1.037	[illegible]	[illegible]	1.021	1.021
2.2	.0752	[illegible]	1.391	1.213	[illegible]	[illegible]	1.094	[illegible]	[illegible]	[illegible]	1.034	[illegible]	[illegible]	1.023
2.3	.0822	.0235	1.420	1.231	1.161	[illegible]	[illegible]	1.071	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.4	[illegible]	[illegible]	[illegible]	[illegible]	1.173	[illegible]	[illegible]	1.077	[illegible]	1.047	[illegible]	[illegible]	[illegible]	1.027
2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.145	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.6	.1051	[illegible]	1.511	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.7	.1133	[illegible]	[illegible]	[illegible]	1.213	[illegible]	1.137	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.8	.1219	[illegible]	1.573	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.9	.1307	.0472	[illegible]	1.341	[illegible]	[illegible]	1.155	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.0	[illegible]	[illegible]	1.637	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.041

Table 9. Coefficients C' to be applied to a discharge given by tables 4, 5, or 6 for a head, H, to give discharge of same weir submerged computed from the formula $C' = \frac{Q'}{Q} = \frac{(nH)^{3/2}}{H}$.

d ÷ H Tenths \ Hundredths	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000	1.006	1.009	1.010	1.011	1.011	1.011	1.009	1.009	1.007
.1	1.007	1.005	1.003	1.000	.997	.994	.991	.988	.983	.981
.2	.978	.973	.970	.966	.963	.958	.955	.951	.946	.942
.3	.939	.935	.931	.926	.921	.917	.913	.909	.903	.900
.4	.895	.891	.885	.881	.875	.871	.865	.859	.854	.848
.5	.842	.837	.831	.825	.819	.812	.806	.799	.792	.785
.6	.778	.771	.764	.756	.748	.740	.733	.723	.715	.707
.7	.698	.689	.680	.670	.660	.649	.639	.626	.615	.603
.8	.589	.576	.562	.547	.531	.517	.501	.486	.469	.453
.9	.435	.416	.396	.375	.351	.323	.293	.255	.209	.144

Table 11 - Free flow discharges in second-feet per foot of width of farmers short-box measuring flume.

Upper gauge head.		2 by 4 inch weir, 0.307 feet high.		2 by 6 inch weir, 0.450 feet high.		2 by 8 inch weir, 0.594 feet high.		2 by 12 inch weir, 0.907 feet high.		2 by 16 inch weir, 1.203 feet high.	
		Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.
Feet.	*Inches.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*
0.20	2 3/8	2 1/4	0.33	2 1/8	0.32	2 1/16	0.31	2 1/16	0.31	2 1/16	0.31
.21	2 1/2	2 3/8	.36	2 3/16	.34	2 3/16	.34	2 1/4	.33	2 1/4	.33
.22	2 5/8	2 7/16	.38	2 5/16	.37	2 1/4	.36	2 3/8	.36	2 3/8	.35
.23	2 3/4	2 9/16	.41	2 3/8	.39	2 3/8	.39	2 1/2	.38	2 1/2	.38
.24	2 7/8	2 11/16	.44	2 1/2	.42	2 1/2	.41	2 9/16	.41	2 9/16	.41
.25	3	2 13/16	.47	2 5/8	.44	2 5/8	.44	2 11/16	.43	2 11/16	.43
.26	3 1/8	2 7/8	.50	2 11/16	.47	2 11/16	.47	2 3/4	.46	2 3/4	.46
.27	3 1/4	2 15/16	.53	2 13/16	.50	2 13/16	.49	2 13/16	.49	2 13/16	.48
.28	3 3/8	3	.56	2 15/16	.53	2 15/16	.52	2 7/8	.52	2 7/8	.51
.29	3 1/2	3 1/8	.59	3 1/16	.56	3	.55	2 15/16	.54	2 15/16	.54
.30	3 5/8	3 3/16	.62	3 1/4	.59	3 1/4	.58	3 3/16	.57	3 3/16	.57
.31	3 3/4	3 5/16	.65	3 3/8	.62	3 5/16	.61	3 5/16	.60	3 1/4	.60
.32	3 13/16	3 7/16	.68	3 1/2	.65	3 7/16	.64	3 3/8	.63	3 3/8	.63
.33	3 15/16	3 1/2	.71	3 9/16	.68	3 9/16	.67	3 1/2	.66	3 1/2	.66
.34	4 1/16	3 5/8	.75	3 11/16	.71	3 5/8	.70	3 9/16	.69	3 9/16	.69
.35	4 3/16	3 3/4	.78	3 13/16	.74	3 3/4	.73	3 11/16	.73	3 11/16	.72
.36	4 5/16	3 13/16	.82	3 7/8	.78	3 13/16	.77	3 3/4	.76	3 3/4	.75
.37	4 7/16	3 15/16	.85	3 15/16	.81	3 7/8	.80	3 13/16	.79	3 13/16	.78
.38	4 9/16	4 1/16	.88	4	.84	3 15/16	.83	3 7/8	.82	3 7/8	.82
.39	4 11/16	4 3/16	.92	4 1/16	.88	4 1/16	.87	4	.85	3 15/16	.85
.40	4 13/16	4 5/16	.96	4 3/16	.91	4 1/8	.90	4 1/16	.89	4 1/16	.88
.41	4 15/16	4 3/8	.99	4 5/16	.94	4 1/4	.93	4 3/16	.92	4 1/8	.92
.42	5 1/16	4 1/2	1.03	4 3/8	.98	4 3/8	.97	4 5/16	.96	4 1/4	.95
.43	5 3/16	4 5/8	1.07	4 1/2	1.02	4 1/2	1.00	4 3/8	.99	4 3/8	.99
.44	5 1/4	4 11/16	1.11	4 5/8	1.05	4 9/16	1.04	4 1/2	1.03	4 7/16	1.02
.45	5 3/8	4 13/16	1.14	4 11/16	1.09	4 11/16	1.08	4 5/8	1.06	4 9/16	1.06
.46	5 1/2	4 15/16	1.18	4 13/16	1.12	4 3/4	1.11	4 11/16	1.10	4 11/16	1.09
.47	5 5/8	5	1.22	4 15/16	1.16	4 7/8	1.15	4 13/16	1.14	4 3/4	1.13
.48	5 3/4	5 1/8	1.26	5	1.20	4 15/16	1.19	4 7/8	1.17	4 7/8	1.17
.49	5 7/8	5 1/4	1.30	5 1/8	1.24	5 1/16	1.22	5	1.21	5	1.20
.50	6	5 3/8	1.34	5 1/4	1.28	5 3/16	1.26	5 1/16	1.25	5 1/16	1.24
.51	6 1/8	5 1/2	1.39	5 5/16	1.32	5 1/4	1.30	5 3/16	1.29	5 3/16	1.28
.52	6 1/4	5 9/16	1.43	5 7/16	1.36	5 3/8	1.34	5 5/16	1.33	5 1/4	1.32
.53	6 3/8	5 11/16	1.47	5 9/16	1.40	5 1/2	1.38	5 3/8	1.37	5 3/8	1.36
.54	6 1/2	5 13/16	1.51	5 11/16	1.44	5 9/16	1.42	5 1/2	1.40	5 1/2	1.40
.55	6 5/8	5 15/16	1.55	5 3/4	1.48	5 11/16	1.46	5 5/8	1.44	5 9/16	1.44
.56	6 3/4	6	1.60	5 7/8	1.52	5 13/16	1.50	5 11/16	1.48	5 11/16	1.48
.57	6 13/16	6 1/8	1.64	5 15/16	1.56	5 7/8	1.54	5 13/16	1.53	5 3/4	1.52
.58	6 15/16	6 1/4	1.69	6 1/16	1.60	6	1.59	5 15/16	1.57	5 7/8	1.56
.59	7 1/16	6 3/8	1.73	6 3/16	1.64	6 1/8	1.63	6	1.61	6	1.60
.60	7 3/16	6 7/16	1.78	6 5/16	1.69	6 3/16	1.67	6 1/8	1.65	6 1/16	1.64
.61	7 5/16	6 9/16	1.82	6 7/16	1.73	6 5/16	1.71	6 3/16	1.69	6 3/16	1.68
.62	7 7/16	6 11/16	1.87	6 1/2	1.77	6 7/16	1.75	6 5/16	1.73	6 1/4	1.72
.63	7 9/16	6 13/16	1.91	6 5/8	1.82	6 1/2	1.80	6 7/16	1.78	6 3/8	1.77
.64	7 11/16	6 7/8	1.96	6 11/16	1.86	6 5/8	1.84	6 1/2	1.82	6 1/2	1.81
.65	7 13/16	7	2.01	6 13/16	1.91	6 3/4	1.89	6 9/16	1.86	6 9/16	1.85
.66	7 15/16	7 1/8	2.06	6 15/16	1.95	6 13/16	1.93	6 11/16	1.91	6 11/16	1.90
.67	8 1/16	7 1/4	2.10	7 1/16	2.00	6 15/16	1.98	6 13/16	1.95	6 3/4	1.94
.68	8 3/16	7 3/8	2.15	7 1/8	2.04	7 1/16	2.02	6 7/8	2.00	6 7/8	1.98
.69	8 5/16	7 7/16	2.20	7 1/4	2.09	7 1/8	2.07	7	2.04	7	2.03

163

Table 11 - Free flow discharges in second-feet per foot of width of farmers short-box measuring flume.

Upper gauge head.		2 by 4 inch weir, 0.307 feet high.		2 by 6 inch weir, 0.450 feet high.		2 by 8 inch weir, 0.594 feet high.		2 by 12 inch weir, 0.907 feet high.		2 by 16 inch weir, 1.203 feet high.	
		Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.
Feet.	*Inches.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*
0.20	2 3/8	2 1/4	0.33	2 1/16	0.32	2 1/16	0.31	2 1/16	0.31	2 1/16	0.31
.21	2 1/2	2 3/8	.36	2 3/16	.34	2 3/16	.34	2 1/8	.33	2 1/8	.33
.22	2 5/8	2 7/16	.38	2 5/16	.37	2 1/4	.36	2 1/4	.36	2 1/4	.35
.23	2 3/4	2 9/16	.41	2 3/8	.39	2 3/8	.39	2 3/8	.38	2 3/8	.38
.24	2 7/8	2 11/16	.44	2 1/2	.42	2 1/2	.41	2 7/16	.41	2 7/16	.41
.25	3	2 13/16	.47	2 5/8	.44	2 5/8	.44	2 9/16	.43	2 9/16	.43
.26	3 1/8	2 7/8	.50	2 11/16	.47	2 11/16	.47	2 5/8	.46	2 5/8	.46
.27	3 1/4	2 7/8	.53	2 13/16	.50	2 13/16	.49	2 3/4	.49	2 3/4	.48
.28	3 3/8	3	.56	2 15/16	.53	2 15/16	.52	2 7/8	.52	2 7/8	.51
.29	3 1/2	3 1/8	.59	3 1/16	.56	3	.55	2 15/16	.54	2 15/16	.54
.30	3 5/8	3 3/16	.62	3 1/8	.59	3 1/8	.58	3 1/16	.57	3 1/16	.57
.31	3 3/4	3 5/16	.65	3 1/4	.62	3 3/16	.61	3 1/8	.60	3 1/8	.60
.32	3 13/16	3 7/16	.68	3 3/8	.65	3 5/16	.64	3 1/4	.63	3 1/4	.63
.33	3 15/16	3 1/2	.71	3 7/16	.68	3 7/16	.67	3 3/8	.66	3 3/8	.66
.34	4 1/16	3 5/8	.75	3 9/16	.71	3 1/2	.70	3 7/16	.69	3 7/16	.69
.35	4 3/16	3 3/4	.78	3 11/16	.74	3 5/8	.73	3 9/16	.73	3 9/16	.72
.36	4 5/16	3 13/16	.82	3 3/4	.78	3 3/4	.77	3 11/16	.76	[illegible]	.75
.37	4 7/16	3 15/16	.85	3 7/8	.81	3 13/16	.80	3 3/4	.79	[illegible]	.78
.38	4 9/16	4 1/16	.88	4	.84	3 15/16	.83	3 7/8	[illegible]	[illegible]	.82
.39	4 11/16	4 3/16	.92	4 1/16	.88	4 1/16	.87	4	[illegible]	3 15/16	.85
.40	4 13/16	4 5/16	.96	4 3/16	.91	4 1/8	.90	4 1/16	[illegible]	4 1/16	.88
.41	4 15/16	4 3/8	.99	4 5/16	.94	4 1/4	.93	4 3/16	.92	4 1/8	.92
.42	5 1/16	4 1/2	1.03	4 3/8	.98	4 3/8	.97	[illegible]	[illegible]	4 1/4	.95
.43	5 3/16	4 5/8	1.07	4 1/2	1.02	4 1/2	1.00	[illegible]	[illegible]	4 3/8	.99
.44	5 5/16	4 11/16	1.11	4 5/8	1.05	4 9/16	1.04	[illegible]	[illegible]	4 7/16	1.02
.45	5 3/8	4 13/16	1.14	4 11/16	1.09	4 11/16	1.08	[illegible]	[illegible]	4 9/16	1.06
.46	5 1/2	4 15/16	1.18	4 13/16	1.12	[illegible]	1.11	[illegible]	1.10	4 11/16	1.09
.47	5 5/8	5	1.22	4 15/16	1.16	4 7/8	1.15	[illegible]	1.14	4 3/4	1.13
.48	5 3/4	5 1/8	1.26	5	1.20	[illegible]	1.19	4 7/8	1.17	4 7/8	1.17
.49	5 7/8	5 1/4	1.30	5 1/8	[illegible]	5 1/16	1.22	5	1.21	5	1.20
.50	6	5 3/8	1.34	5 1/4	[illegible]	5 3/16	1.26	5 1/16	1.25	5 1/16	1.24
.51	6 1/8	5 1/2	1.39	5 5/16	1.32	5 1/4	1.30	5 3/16	1.29	5 3/16	1.28
.52	6 1/4	5 9/16	1.43	5 7/16	1.36	5 3/8	1.34	5 5/16	1.33	5 1/4	1.32
.53	6 3/8	5 11/16	1.47	5 9/16	1.40	5 1/2	1.38	5 3/8	1.37	5 3/8	1.36
.54	6 1/2	5 13/16	1.51	5 11/16	1.44	5 9/16	1.42	5 1/2	1.40	5 1/2	1.40
.55	6 5/8	5 15/16	1.55	[illegible]	1.48	5 11/16	1.46	5 5/8	1.44	5 9/16	1.44
.56	6 3/4	6	1.60	[illegible]	1.52	5 13/16	1.50	5 11/16	1.48	5 11/16	1.48
.57	6 13/16	6 1/8	1.64	5 15/16	1.56	5 7/8	1.54	5 13/16	1.53	5 3/4	1.52
.58	6 15/16	6 1/4	1.69	6 1/16	1.60	6	1.59	5 15/16	1.57	5 7/8	1.56
.59	7 1/16	6 3/8	1.73	6 3/16	1.64	6 1/8	1.63	6	1.61	6	1.60
.60	7 3/16	6 7/16	1.78	6 5/16	1.69	6 3/16	1.67	6 1/8	1.65	6 1/16	1.64
.61	7 5/16	6 9/16	1.82	6 7/16	1.73	6 5/16	1.71	6 3/16	1.69	6 3/16	1.68
.62	7 7/16	6 11/16	1.87	6 1/2	1.77	6 7/16	1.75	6 5/16	1.73	6 1/4	1.72
.63	7 9/16	6 13/16	1.91	6 5/8	1.82	6 1/2	1.80	6 7/16	1.78	6 3/8	1.77
.64	7 11/16	6 7/8	1.96	6 11/16	1.86	6 5/8	1.84	6 1/2	1.82	6 1/2	1.81
.65	7 13/16	7	2.01	6 13/16	1.91	6 3/4	1.89	6 9/16	1.86	6 9/16	1.85
.66	7 15/16	7 1/8	2.05	6 15/16	1.95	6 13/16	1.93	6 11/16	1.91	6 11/16	1.90
.67	8 1/16	7 1/4	2.10	7 1/16	2.00	6 15/16	1.98	6 13/16	1.95	6 3/4	1.94
.68	8 3/16	7 3/8	2.15	7 1/8	2.04	7 1/16	2.02	6 7/8	2.00	6 7/8	1.98
.69	8 5/16	7 7/16	2.20	7 1/4	2.09	7 1/8	2.07	7	2.04	7	2.03

See Negative

Table 15. Free-flow discharge through 3-inch Parshall measuring flume.
Based on $Q=0.992\ Ha^{1.547}$

Upper head Ha	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
Feet	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
0.10	[illegible]	[illegible]	.037	.042	.047	.053	.058	.064	.070	.076
.20	.082	[illegible]	.095	.103	.109	.117	.124	.131	.138	.146
.30	.154	.162	.170	.179	.187	.196	.205	.213	.222	.231
.40	.241	.250	.260	.269	.279	.289	.299	.309	.319	.329
.50	.339	.350	.361	.371	.382	.393	.404	.415	.427	.438
.60	.450	.462	.474	.485	.497	.509	.522	.534	.546	.558
.70	.571	.584	.597	.610	.623	.636	.649	.662	.675	.689
.80	.702	.716	.730	.744	.757	.771	.785	.800	.814	.828
.90	.843	.857	.872	.887	.902	.916	.931	.946	.961	.977
1.00	.992	1.007	1.023	1.038	1.054	1.070	1.086	1.102	1.118	1.134

Table 16. Free-flow discharge through 6-inch Parshall measuring flume.
Based on $Q=2.06\ Ha^{1.58}$

Upper head Ha	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
Feet	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
0.10	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15
.20	.16	.18	.19	.20	.22	.23	.25	.26	.28	.29
.30	.31	.33	.34	.36	.38	.39	.41	.43	.45	.47
.40	.48	.50	.52	.54	.56	.58	.61	.63	.65	.67
.50	.69	.71	.73	.76	.78	.80	.82	.85	.87	.89
.60	.92	.94	.97	.99	1.02	1.04	1.07	1.10	1.12	1.15
.70	1.17	1.20	1.23	1.26	1.28	1.31	1.34	1.36	1.39	1.42
.80	1.45	1.48	1.50	1.53	1.56	1.59	1.62	1.65	1.68	1.71
.90	1.74	1.77	1.81	1.84	1.87	1.90	1.93	1.97	2.00	2.03
1.00	2.06	2.09	2.12	2.16	2.19	2.22	2.26	2.29	2.33	2.36
1.10	2.40	2.43	2.46	2.50	2.53	2.57	2.60	2.64	2.68	2.71
1.20	2.75	2.78	2.82	2.86	2.89	2.93	2.97	3.01	3.04	3.08

Table 17. Free-flow discharge through 9-inch Parshall measuring flume.
Based on $Q=3.07\ Ha^{1.53}$

Upper head Ha	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
Feet	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
0.10	0.09	0.10	0.12	0.14	0.15	0.17	0.19	0.20	0.22	0.24
.20	.26	.28	.30	.32	.35	.37	.39	.41	.44	.46
.30	.49	.51	.54	.56	.59	.62	.64	.67	.70	.73
.40	.76	.78	.81	.84	.87	.90	.94	.97	1.00	1.03
.50	1.06	1.10	1.13	1.16	1.20	1.23	1.26	1.30	1.33	1.37
.60	1.40	1.44	1.48	1.51	1.55	1.59	1.63	1.66	1.70	1.74
.70	1.78	1.82	1.86	1.90	1.94	1.98	2.02	2.06	2.10	2.14
.80	2.18	2.22	2.27	2.31	2.35	2.39	2.44	2.48	2.52	2.57
.90	2.61	2.66	2.70	2.75	2.79	2.84	2.88	2.93	2.98	3.02
1.00	3.07	3.12	3.17	3.21	3.26	3.31	3.36	3.40	3.45	3.50
1.10	3.55	3.60	3.65	3.70	3.75	3.80	3.85	3.90	3.95	4.01
1.20	4.06	4.11	4.16	4.22	4.27	4.32	4.37	4.43	4.48	4.53
1.30	4.59	4.64	4.69	4.75	4.80	4.86	4.92	4.97	5.03	5.08
1.40	5.14	5.19	5.25	5.31	5.37	5.42	5.48	5.54	5.59	5.65
1.50	5.71	5.77	5.83	5.89	5.94	6.00	6.06	6.12	6.18	6.24

Table 18. Free-flow discharge for Parshall measuring flume.

Computed from the formula $Q = 4WHa^{1.522W^{0.026}}$

Upper Head Ha		Discharge per second for flumes of various throat widths							
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet
Feet	Inches	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
0.20	2-3/8	0.35	0.66	0.97	1.26				
.21	2-1/2	.37	.71	1.03	1.36				
.22	2-5/8	.40	.77	1.12	1.47				
.23	2-3/4	.43	.82	1.20	1.58				
.24	2-7/8	.46	.88	1.28	1.69				
.25	3	.49	.93	1.37	1.80	2.22	2.63		
.26	3-1/8	.51	.99	1.46	1.91	2.36	2.80		
.27	3-1/4	.54	1.05	1.55	2.03	2.50	2.97		
.28	3-3/8	.58	1.11	1.64	2.15	2.65	3.15		
.29	3-1/2	.61	1.18	1.73	2.27	2.80	3.33		
.30	3-5/8	.64	1.24	1.82	2.39	2.96	3.52	4.08	4.62
.31	3-3/4	.68	1.30	1.92	2.52	3.12	3.71	4.30	4.88
.32	3-13/16	.71	1.37	2.02	2.65	3.28	3.90	4.52	5.13
.33	3-15/16	.75	1.44	2.12	2.78	3.44	4.10	4.75	5.39
.34	4-1/16	.77	1.50	2.22	2.92	3.61	4.30	4.98	5.66
.35	4-3/16	.80	1.57	2.32	3.06	3.78	4.50	5.22	5.93
.36	4-5/16	.84	1.64	2.42	3.20	3.95	4.71	5.46	6.20
.37	4-7/16	.88	1.72	2.53	3.34	4.13	4.92	5.70	6.48
.38	4-9/16	.92	1.79	2.64	3.48	4.31	5.13	5.95	6.76
.39	4-11/16	.95	1.86	2.75	3.62	4.49	5.35	6.20	7.05
.40	4-13/16	.99	1.93	2.86	3.77	4.68	5.57	6.46	7.34
.41	4-15/16	1.03	2.01	2.97	3.92	4.86	5.80	6.72	7.64
.42	5-1/16	1.07	2.09	3.08	4.07	5.05	6.02	6.98	7.94
.43	5-3/16	1.11	2.16	3.20	4.22	5.24	6.25	7.25	8.24
.44	5-1/4	1.15	2.24	3.32	4.38	5.43	6.48	7.52	8.55
.45	5-3/8	1.19	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.46	5-1/2	1.23	2.40	3.56	4.70	5.83	6.96	8.08	9.19
.47	5-5/8	1.27	2.48	3.68	4.86	6.03	7.20	8.36	9.51
.48	5-3/4	1.31	2.57	3.80	5.02	6.24	7.44	8.65	9.84
.49	5-7/8	1.35	2.65	3.92	5.18	6.45	7.69	8.94	10.17
.50	6	1.39	2.73	4.05	5.36	6.66	7.94	9.23	10.51
.51	6-1/8	1.44	2.82	4.18	5.53	6.87	8.20	9.53	10.85
.52	6-1/4	1.48	2.90	4.31	5.70	7.08	8.46	9.83	11.19
.53	6-3/8	1.52	2.99	4.44	5.88	7.30	8.72	10.14	11.54
.54	6-1/2	1.57	3.08	4.57	6.05	7.52	8.98	10.45	11.89
.55	6-5/8	1.61	3.17	4.70	6.23	7.74	9.25	10.76	12.24
.56	6-3/4	1.66	3.26	4.84	6.41	7.97	9.52	11.07	12.60
.57	6-13/16	1.70	3.35	4.98	6.59	8.20	9.79	11.39	12.96
.58	6-15/16	1.75	3.44	5.11	6.77	8.43	10.07	11.71	13.33
.59	7-1/16	1.80	3.53	5.25	6.96	8.66	10.35	12.03	13.70
.60	7-3/16	1.84	3.62	5.39	7.15	8.89	10.63	12.36	14.08
.61	7-5/16	1.89	3.72	5.53	7.34	9.13	10.92	12.69	14.46
.62	7-7/16	1.93	3.81	5.68	7.53	9.37	11.20	13.02	14.84
.63	7-9/16	1.98	3.91	5.82	7.72	9.61	11.49	13.36	15.23
.64	7-11/16	2.03	4.01	5.97	7.91	9.85	11.78	13.70	15.62
.65	7-13/16	2.08	4.11	6.12	8.11	10.10	12.08	14.05	16.01
.66	7-15/16	2.13	4.20	6.26	8.31	10.34	12.38	14.40	16.41
.67	8-1/16	2.18	4.30	6.41	8.51	10.59	12.68	14.75	16.81
.68	8-3/16	2.23	4.40	6.56	8.71	10.85	12.98	15.10	17.22
.69	8-1/4	2.28	4.50	6.71	8.91	11.10	13.28	15.46	17.63
.70	8-3/8	2.33	4.60	6.86	9.11	11.36	13.59	15.82	18.04
.71	8-1/2	2.38	4.70	7.02	9.32	11.62	13.90	16.18	18.45
.72	8-5/8	2.43	4.81	7.17	9.53	11.88	14.22	16.55	18.87
.73	8-3/4	2.48	4.91	7.33	9.74	12.14	14.53	16.92	19.29
.74	8-7/8	2.53	5.02	7.49	9.95	12.40	14.85	17.29	19.71
.75	9	2.58	5.12	7.65	10.16	12.67	15.17	17.66	20.14
.76	9-1/8	2.63	5.23	7.81	10.38	12.94	15.49	18.04	20.57
.77	9-1/4	2.68	5.34	7.97	10.60	13.21	15.82	18.42	21.01
.78	9-3/8	2.74	5.44	8.13	10.81	13.48	16.15	18.81	21.46
.79	9-1/2	2.80	5.55	8.30	11.03	13.76	16.48	19.20	21.91
.80	9-5/8	2.85	5.66	8.46	11.25	14.04	16.81	19.59	22.36
.81	9-3/4	2.90	5.77	8.62	11.48	14.32	17.15	19.99	22.81
.82	9-13/16	2.96	5.88	8.79	11.70	14.60	17.49	20.38	23.26
.83	9-15/16	3.02	6.00	8.96	11.92	14.88	17.83	20.78	23.72
.84	10-1/16	3.07	6.11	9.13	12.15	15.17	18.17	21.18	24.18
.85	10-3/16	3.13	6.22	9.30	12.38	15.46	18.52	21.58	24.64
.86	10-5/16	3.19	6.33	9.48	12.61	15.75	18.87	21.99	25.11
.87	10-7/16	3.24	6.44	9.65	12.84	16.04	19.22	22.40	25.58
.88	10-9/16	3.30	6.56	9.82	13.07	16.33	19.57	22.82	26.05
.89	10-11/16	3.36	6.68	10.00	13.31	16.62	19.93	23.24	26.54

Table 18. Free-flow discharge for Parshall measuring flume. (continued)
Computed from the formula $Q = 4WHa^{1.522W^{0.026}}$

Upper Head H_a Feet	Inches	Discharge per second for flumes of various throat widths: 1 Foot Cu. ft.	2 Feet Cu. ft.	3 Feet Cu. ft.	4 Feet Cu. ft.	5 Feet Cu. ft.	6 Feet Cu. ft.	7 Feet Cu. ft.	8 Feet Cu. ft.
.90	10 13/16	3.41	6.80	10.17	13.55	16.92	20.29	23.66	27.02
.91	10 15/16	3.46	6.92	10.35	13.79	17.22	20.65	24.08	27.50
.92	11 1/16	3.52	7.03	10.53	14.03	17.52	21.01	24.50	27.99
.93	11 3/16	3.58	7.15	10.71	14.27	17.82	21.38	24.93	28.48
.94	11 1/4	3.64	7.27	10.89	14.51	18.12	21.75	25.36	28.97
.95	11 3/8	3.70	7.39	11.07	14.76	18.44	22.12	25.79	29.47
.96	11 1/2	3.76	7.51	11.26	15.00	18.75	22.49	26.22	29.97
.97	11 5/8	3.82	7.63	11.44	15.25	19.06	22.86	26.66	30.48
.98	11 3/4	3.88	7.75	11.63	15.50	19.37	23.24	27.10	30.98
.99	11 7/8	3.94	7.88	11.82	15.75	19.68	23.62	27.55	31.49
1.00	12	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00
1.01	12 1/8	4.06	8.12	12.19	16.25	20.32	24.38	28.45	32.52
1.02	12 1/4	4.12	8.25	12.38	16.51	20.64	24.77	28.90	33.04
1.03	12 3/8	4.18	8.38	12.57	16.76	20.96	25.16	29.36	33.56
1.04	12 1/2	4.25	8.50	12.76	17.02	21.28	25.55	29.82	34.08
1.05	12 5/8	4.31	8.63	12.96	17.28	21.61	25.94	30.28	34.61
1.06	12 3/4	4.37	8.76	13.15	17.54	21.94	26.34	30.74	35.14
1.07	12 13/16	4.43	8.88	13.34	17.80	22.27	26.74	31.20	35.68
1.08	12 15/16	4.50	9.01	13.54	18.07	22.60	27.13	31.67	36.22
1.09	13 1/16	4.56	9.14	13.74	18.34	22.93	27.53	32.14	36.76
1.10	13 3/16	4.62	9.27	13.93	18.60	23.26	27.94	32.62	37.30
1.11	13 5/16	4.68	9.40	14.13	18.86	23.60	28.35	33.10	37.84
1.12	13 7/16	4.75	9.54	14.33	19.13	23.94	28.76	33.58	38.39
1.13	13 9/16	4.82	9.67	14.53	19.40	24.28	29.17	34.06	38.94
1.14	13 11/16	4.88	9.80	14.73	19.67	24.62	29.58	34.54	39.50
1.15	13 13/16	4.94	9.94	14.94	19.94	24.96	30.00	35.02	40.06
1.16	13 15/16	5.01	10.07	15.14	20.22	25.31	30.41	35.51	40.62
1.17	14 1/16	5.08	10.20	15.34	20.50	25.66	30.83	36.00	41.18
1.18	14 3/16	5.15	10.34	15.55	20.78	26.01	31.25	36.50	41.75
1.19	14 1/4	5.21	10.48	15.76	21.05	26.36	31.68	37.00	42.32
1.20	14 3/8	5.28	10.61	15.96	21.33	26.71	32.10	37.50	42.89
1.21	14 1/2	5.34	10.75	16.17	21.61	27.06	32.53	38.00	43.47
1.22	14 5/8	5.41	10.89	16.38	21.90	27.42	32.96	38.50	44.05
1.23	14 3/4	5.48	11.03	16.60	22.18	27.78	33.39	39.00	44.64
1.24	14 7/8	5.55	11.17	16.81	22.47	28.14	33.82	39.51	45.22
1.25	15	5.62	11.31	17.02	22.75	28.50	34.26	40.02	45.80
1.26	15 1/8	5.69	11.45	17.23	23.04	28.86	34.70	40.54	46.38
1.27	15 1/4	5.76	11.59	17.44	23.33	29.22	35.14	41.05	46.97
1.28	15 3/8	5.82	11.73	17.66	23.62	29.59	35.58	41.57	47.57
1.29	15 1/2	5.89	11.87	17.88	23.92	29.96	36.02	42.09	48.17
1.30	15 5/8	5.96	12.01	18.10	24.21	30.33	36.47	42.62	48.77
1.31	15 3/4	6.03	12.16	18.32	24.50	30.70	36.92	43.14	49.38
1.32	15 13/16	6.10	12.30	18.54	24.80	31.07	37.37	43.67	49.99
1.33	15 15/16	6.18	12.44	18.76	25.10	31.44	37.82	44.20	50.60
1.34	16 1/16	6.25	12.59	18.98	25.39	31.82	38.28	44.73	51.22
1.35	16 3/16	6.32	12.74	19.20	25.69	32.20	38.74	45.26	51.84
1.36	16 5/16	6.39	12.89	19.42	25.99	32.58	39.20	45.80	52.46
1.37	16 7/16	6.46	13.03	19.64	26.30	32.96	39.66	46.35	53.08
1.38	16 9/16	6.53	13.18	19.87	26.60	33.34	40.12	46.89	53.70
1.39	16 11/16	6.60	13.33	20.10	26.90	33.72	40.58	47.44	54.33
1.40	16 13/16	6.68	13.48	20.32	27.21	34.11	41.05	47.99	54.96
1.41	16 15/16	6.75	13.63	20.55	27.52	34.50	41.52	48.54	55.59
1.42	17 1/16	6.82	13.78	20.78	27.82	34.89	41.99	49.09	56.22
1.43	17 3/16	6.89	13.93	21.01	28.14	35.28	42.46	49.64	56.86
1.44	17 1/4	6.97	14.08	21.24	28.45	35.67	42.94	50.20	57.50
1.45	17 3/8	7.04	14.23	21.47	28.76	36.06	43.42	50.76	58.14
1.46	17 1/2	7.12	14.38	21.70	29.07	36.46	43.89	51.32	58.78
1.47	17 5/8	7.19	14.54	21.94	29.38	36.86	44.37	51.88	59.43
1.48	17 3/4	7.26	14.69	22.17	29.70	37.26	44.85	52.45	60.08
1.49	17 7/8	7.34	14.85	22.41	30.02	37.66	45.34	53.02	60.74
1.50	18	7.41	15.00	22.64	30.34	38.06	45.82	53.59	61.40
1.51	18 1/8	7.49	15.16	22.88	30.66	38.46	46.31	54.16	62.06
1.52	18 1/4	7.57	15.31	23.12	30.98	38.87	46.80	54.74	62.72
1.53	18 3/8	7.64	15.47	23.36	31.30	39.28	47.30	55.32	63.38
1.54	18 1/2	7.72	15.62	23.60	31.62	39.68	47.79	55.90	64.04
1.55	18 5/8	7.80	15.78	23.84	31.95	40.09	48.28	56.48	64.71
1.56	18 3/4	7.87	15.94	24.08	32.27	40.51	48.78	57.06	65.38
1.57	18 13/16	7.95	16.10	24.32	32.60	40.92	49.28	57.65	66.06
1.58	18 15/16	8.02	16.26	24.56	32.93	41.33	49.78	58.24	66.74
1.59	19 1/16	8.10	16.42	24.80	33.26	41.75	50.28	58.83	67.42

Table 18. Free-flow discharge for Parshall measuring flume. (continued)
Computed from the formula $Q=4WH_a^{1.522W^{0.026}}$

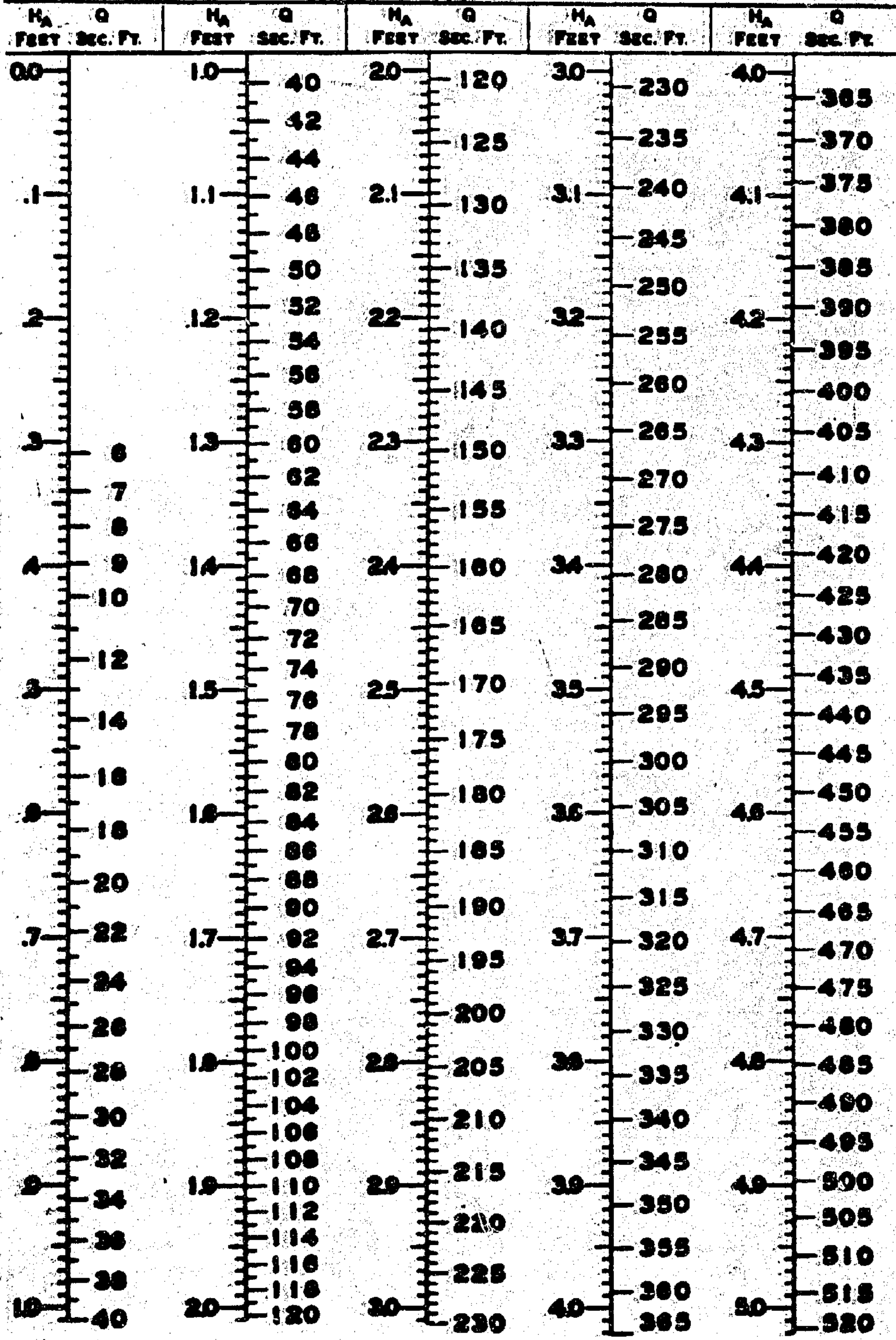
Upper Head H_a		Discharge per second for flumes of various throat widths							
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet
Feet	Inches	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
1.60	19 3/16	8.18	16.58	25.05	33.59	42.17	50.79	59.42	68.10
1.61	19 5/16	8.26	16.74	25.30	33.92	42.59	51.30	60.02	68.79
1.62	19 7/16	8.34	16.90	25.54	34.26	43.01	51.81	60.62	69.48
1.63	19 9/16	8.42	17.06	25.79	34.60	43.43	52.32	61.22	70.17
1.64	19 11/16	8.49	17.22	26.04	34.93	43.86	52.83	61.82	70.86
1.65	19 13/16	8.57	17.38	26.29	35.26	44.28	53.34	62.42	71.56
1.66	19 15/16	8.65	17.55	26.54	35.60	44.70	53.86	63.03	72.26
1.67	20 1/16	8.73	17.72	26.79	35.94	45.13	54.38	63.64	72.96
1.68	20 3/16	8.81	17.88	27.04	36.28	45.56	54.90	64.25	73.66
1.69	20 1/4	8.89	18.04	27.30	36.62	46.00	55.42	64.86	74.37
1.70	20 3/8	8.97	18.21	27.55	36.96	46.43	55.95	65.48	75.08
1.71	20 1/2	9.05	18.38	27.80	37.30	46.86	56.48	66.10	75.79
1.72	20 5/8	9.13	18.54	28.06	37.65	47.30	57.00	66.72	76.50
1.73	20 3/4	9.21	18.71	28.32	38.00	47.74	57.53	67.34	77.22
1.74	20 7/8	9.29	18.88	28.57	38.34	48.17	58.06	67.96	77.94
1.75	21	9.38	19.04	28.82	38.69	48.61	58.60	68.59	78.66
1.76	21 1/8	9.46	19.21	29.08	39.04	49.05	59.13	69.22	79.38
1.77	21 1/4	9.54	19.38	29.34	39.39	49.50	59.67	69.85	80.10
1.78	21 3/8	9.62	19.55	29.60	39.74	49.94	60.20	70.48	80.83
1.79	21 1/2	9.70	19.72	29.87	40.10	50.38	60.74	71.11	81.56
1.80	21 5/8	9.79	19.90	30.12	40.45	50.83	61.29	71.75	82.29
1.81	21 3/4	9.87	20.07	30.39	40.80	51.28	61.83	72.39	83.03
1.82	21 13/16	9.95	20.24	30.65	41.16	51.73	62.38	73.03	83.77
1.83	21 15/16	10.04	20.42	30.92	41.52	52.18	62.92	73.68	84.51
1.84	22 1/16	10.12	20.59	31.18	41.88	52.64	63.46	74.33	85.25
1.85	22 3/16	10.20	20.76	31.45	42.24	53.09	64.01	74.98	86.00
1.86	22 5/16	10.29	20.93	31.71	42.60	53.55	64.57	75.63	86.75
1.87	22 7/16	10.38	21.10	31.98	42.96	54.00	65.13	76.28	87.50
1.88	22 9/16	10.46	21.28	32.25	43.32	54.46	65.69	76.93	88.25
1.89	22 11/16	10.54	21.46	32.52	43.69	54.92	66.25	77.58	89.00
1.90	22 13/16	10.62	21.63	32.79	44.05	55.39	66.81	78.24	89.76
1.91	22 15/16	10.71	21.81	33.06	44.42	55.85	67.37	78.90	90.52
1.92	23 1/16	10.80	21.99	33.33	44.79	56.32	67.93	79.56	91.29
1.93	23 3/16	10.88	22.17	33.60	45.16	56.78	68.50	80.23	92.05
1.94	23 1/4	10.97	22.35	33.87	45.53	57.25	69.06	80.90	92.82
1.95	23 3/8	11.06	22.53	34.14	45.90	57.72	69.63	81.57	93.59
1.96	23 1/2	11.14	22.70	34.42	46.27	58.19	70.20	82.24	94.36
1.97	23 5/8	11.23	22.88	34.70	46.64	58.67	70.78	82.91	95.14
1.98	23 3/4	11.31	23.06	34.97	47.02	59.14	71.35	83.58	95.92
1.99	23 7/8	11.40	23.24	35.25	47.40	59.61	71.92	84.26	96.70
2.00	24	11.49	23.43	35.53	47.77	60.08	72.50	84.94	97.48
2.01	24 1/8	11.58	23.61	35.81	48.14	60.56	73.08	85.62	98.26
2.02	24 1/4	11.66	23.79	36.09	48.52	61.04	73.66	86.30	99.05
2.03	24 3/8	11.75	23.98	36.37	48.90	61.52	74.24	86.99	99.84
2.04	24 1/2	11.84	24.16	36.65	49.29	62.00	74.83	87.68	100.6
2.05	24 5/8	11.93	24.34	36.94	49.67	62.48	75.42	88.37	101.4
2.06	24 3/4	12.02	24.52	37.22	50.05	62.97	76.00	89.06	102.2
2.07	24 13/16	12.10	24.70	37.50	50.44	63.46	76.59	89.75	103.0
2.08	24 15/16	12.19	24.89	37.78	50.82	63.94	77.19	90.44	103.8
2.09	25 1/16	12.28	25.08	38.06	51.21	64.43	77.78	91.14	104.6
2.10	25 3/16	12.37	25.27	38.35	51.59	64.92	78.37	91.84	105.4
2.11	25 5/16	12.46	25.46	38.64	51.98	65.41	78.97	92.54	106.2
2.12	25 7/16	12.55	25.64	38.93	52.37	65.91	79.56	93.25	107.0
2.13	25 9/16	12.64	25.83	39.22	52.76	66.40	80.15	93.95	107.9
2.14	25 11/16	12.73	26.01	39.50	53.15	66.89	80.75	94.66	108.7
2.15	25 13/16	12.82	26.20	39.79	53.54	67.39	81.36	95.37	109.5
2.16	25 15/16	12.92	26.39	40.08	53.94	67.89	81.97	96.08	110.3
2.17	26 1/16	13.01	26.58	40.37	54.34	68.39	82.58	96.79	111.1
2.18	26 3/16	13.10	26.77	40.66	54.73	68.89	83.19	97.51	111.9
2.19	26 1/4	13.19	26.96	40.96	55.12	69.39	83.80	98.23	112.8
2.20	26 3/8	13.28	27.15	41.25	55.52	69.90	84.41	98.94	113.6
2.21	26 1/2	13.37	27.34	41.54	55.92	70.40	85.02	99.66	114.4
2.22	26 5/8	13.46	27.54	41.84	56.32	70.90	85.63	100.4	115.3
2.23	26 3/4	13.56	27.73	42.13	56.72	71.41	86.25	101.1	116.1
2.24	26 7/8	13.65	27.92	42.43	57.12	71.92	86.87	101.8	116.9
2.25	27	13.74	28.12	42.73	57.52	72.43	87.49	102.6	117.8
2.26	27 1/8	13.84	28.31	43.02	57.93	72.94	88.11	103.3	118.6
2.27	27 1/4	13.93	28.50	43.32	58.34	73.46	88.73	104.0	119.5
2.28	27 3/8	14.02	28.70	43.62	58.74	73.97	89.35	104.8	120.3
2.29	27 1/2	14.12	28.90	43.92	59.15	74.49	89.98	105.5	121.2

Table 18. Free-flow discharge for Parshall measuring flume. (continued)
Computed from the formula $=4 Ha^{1.522} 0.026$

Upper Head H_a		Discharge per second for flumes of various throat widths							
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet
Feet	Inches	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
2.30	27⅝	14.21	29.09	44.22	59.56	75.01	90.61	106.2	122.0
2.31	27¾	14.30	29.29	44.52	59.96	75.53	91.24	107.0	122.9
2.32	27 13/16	14.40	29.49	44.83	60.37	76.05	91.87	107.7	123.7
2.33	27 15/16	14.49	29.69	45.13	60.79	76.57	92.50	108.5	124.6
2.34	28 1/16	14.59	29.89	45.43	61.20	77.09	93.14	109.2	125.4
2.35	28 3/16	14.68	30.08	45.74	61.61	77.61	93.77	110.0	126.3
2.36	28 5/16	14.78	30.28	46.04	62.03	78.13	94.41	110.7	127.2
2.37	28 7/16	14.87	30.48	46.35	62.44	78.66	95.05	111.5	128.0
2.38	28 9/16	14.97	30.69	46.66	62.86	79.19	95.69	112.2	128.9
2.39	28 11/16	15.07	30.89	46.96	63.27	79.72	96.33	113.0	129.8
2.40	28 13/16	15.16	31.09	47.27	63.69	80.25	96.97	113.7	130.7
2.41	28 15/16	15.26	31.29	47.58	64.11	80.78	97.62	114.5	131.5
2.42	29 1/16	15.35	31.49	47.89	64.53	81.31	98.27	115.3	132.4
2.43	29 3/16	15.45	31.69	48.20	64.95	81.84	98.91	116.0	133.3
2.44	29¼	15.55	31.89	48.51	65.38	82.38	99.56	116.8	134.2
2.45	29⅜	15.64	32.10	48.82	65.80	82.92	100.2	117.6	135.1
2.46	29½	15.74	32.30	49.13	66.23	83.45	100.9	118.3	135.9
2.47	29⅝	15.84	32.50	49.45	66.65	83.99	101.5	119.1	136.8
2.48	29¾	15.94	32.70	49.76	67.07	84.53	102.2	119.9	137.7
2.49	29⅞	16.03	32.90	50.08	67.50	85.07	102.8	120.6	138.6
2.50	30	16.13	33.11	50.39	67.93	85.62	103.5	121.4	139.5

169

Table 19. Free-flow discharge 10-foot Parshall measuring flume.
Formula $Q = 39.38\ Ha^{1.6}$



170

Table 20. Free-flow discharge 12-foot Parshall measuring flume.
Formula $Q=46.75\ Ha^{1.6}$

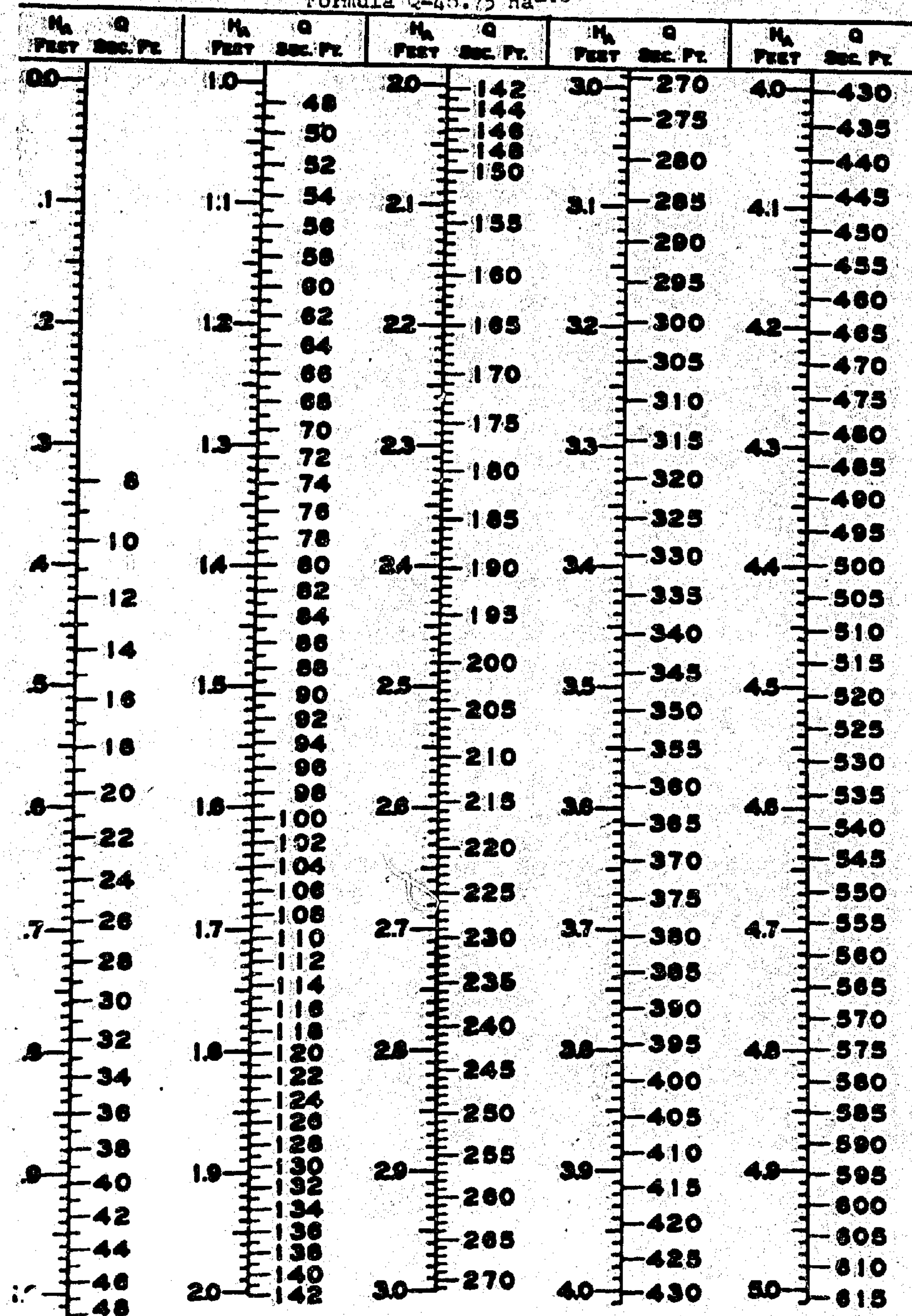


Table 21. Free-flow discharge 15-foot Parshall measuring flume.
Formula $Q=57.81\ Ha^{1.6}$

Scale 1
- H_A Feet: 0.0, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1.0
- Q Sec. Ft.: 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58

Scale 2
- H_A Feet: 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0
- Q Sec. Ft.: 58, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175

Scale 3
- H_A Feet: 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0
- Q Sec. Ft.: 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335

Scale 4
- H_A Feet: 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0
- Q Sec. Ft.: 335, 340, 345, 350, 355, 360, 365, 370, 375, 380, 385, 390, 395, 400, 405, 410, 415, 420, 425, 430, 435, 440, 445, 450, 455, 460, 465, 470, 475, 480, 485, 490, 495, 500, 505, 510, 515, 520, 525, 530

Scale 5
- H_A Feet: 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0
- Q Sec. Ft.: 530, 535, 540, 545, 550, 555, 560, 565, 570, 575, 580, 585, 590, 595, 600, 605, 610, 615, 620, 625, 630, 635, 640, 645, 650, 655, 660, 665, 670, 675, 680, 685, 690, 695, 700, 705, 710, 715, 720, 725, 730, 735, 740, 745, 750, 755, 760

Scale 6
- H_A Feet: 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0
- Q Sec. Ft.: 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000, 1010, 1020

172

Table 22. Free-flow discharge 20-foot Parshall measuring flume.
Formula $Q=76.25\ Ha^{1.6}$

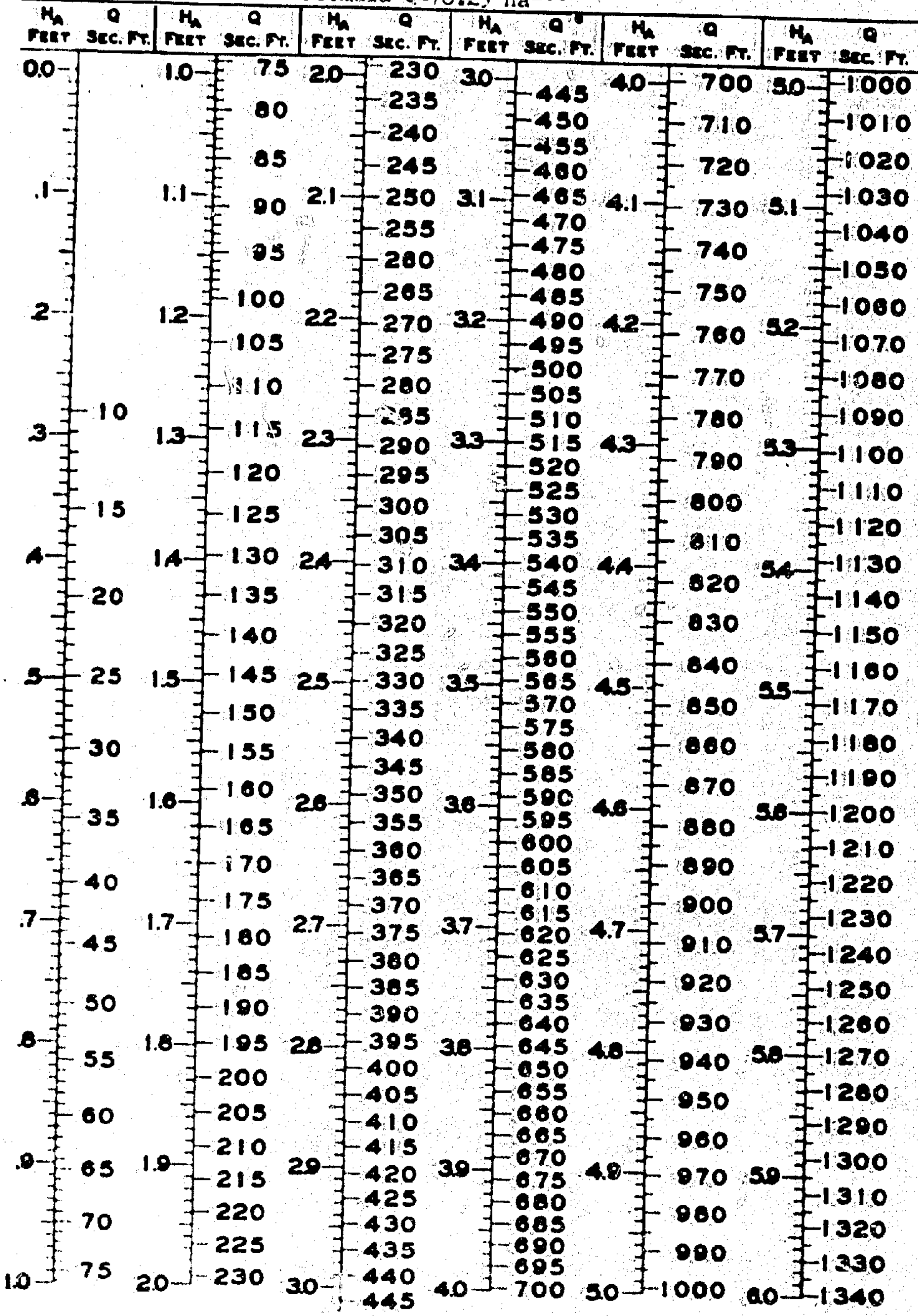


Table 22. Free-flow discharge 25-foot Parshall measuring flume.
Formula $Q=94.67\ Ha^{1.6}$

H_A Feet	Q Sec. Ft.	H_A Feet	Q Sec. Ft.	H_A Feet	Q Sec. Ft.	H_A Feet	Q Sec. Ft.	H_A Feet	Q Sec. Ft.	H_A Feet	Q Sec. Ft.
0.0	15	1.0	95	2.0	290	3.0	550	4.0	870	5.0	1250
.1	20	1.1	100	2.1	300	3.1	560	4.1	880	5.1	1260
.2	25	1.2	105	2.2	310	3.2	570	4.2	890	5.2	1270
.3	30	1.3	110	2.3	320	3.3	580	4.3	900	5.3	1280
.4	35	1.4	115	2.4	330	3.4	590	4.4	910	5.4	1290
.5	40	1.5	120	2.5	340	3.5	600	4.5	920	5.5	1300
.6	45	1.6	125	2.6	350	3.6	610	4.6	930	5.6	1310
.7	50	1.7	130	2.7	360	3.7	620	4.7	940	5.7	1320
.8	55	1.8	135	2.8	370	3.8	630	4.8	950	5.8	1330
.9	60	1.9	140	2.9	380	3.9	640	4.9	960	5.9	1340
1.0	65	2.0	145	3.0	390	4.0	650	5.0	970	6.0	1350
	70		150		400		660		980		1360
	75		155		410		670		990		1370
	80		160		420		680		1000		1380
	85		165		430		690		1010		1480
	90		170		440		700		1020		1400
	95		175		450		710		1030		1410
			180		460		720		1040		1420
			185		470		730		1050		1430
			190		480		740		1060		1440
			195		490		750		1070		1450
			200		500		760		1080		1460
			205		510		770		1090		1470
			210		520		780		1100		1480
			215		530		790		1110		1490
			220		540		800		1120		1500
			225		550		810		1130		1510
			230				820		1140		1520
			235				830		1150		1530
			240				840		1160		1540
			245				850		1170		1550
			250				860		1180		1560
			255				870		1190		1570
			260						1200		1580
			265						1210		1590
			270						1220		1600
			275						1230		1610
			280						1240		1620
			285						1250		1630
			290								1640
											1650
											1660
											1670

Table 24. Free-flow discharge 30-foot Parshall measuring flume.
Formula $Q=113.13\ Ha^{1.6}$

H_A Feet	Q Sec. Ft.
0.0	
.1	
.2	
	15
.3	
	20
.4	25
	30
	35
.5	
	40
	45
.6	50
	55
	60
.7	65
	70
	75
.8	80
	85
	90
.9	95
	100
	105
	110
1.0	115

H_A Feet	Q Sec. Ft.
1.0	115
	120
	125
1.1	130
	135
	140
	145
1.2	150
	155
	160
	165
1.3	170
	175
	180
	185
	190
1.4	195
	200
	205
	210
1.5	215
	220
	225
	230
	235
1.6	240
	245
	250
	255
	260
1.7	265
	270
	275
	280
	285
1.8	290
	295
	300
	305
	310
1.9	315
	320
	325
	330
	335
	340
2.0	345

H_A Feet	Q Sec. Ft.
2.0	345
	350
	360
2.1	370
	380
	390
2.2	400
	410
	420
2.3	430
	440
	450
2.4	460
	470
	480
2.5	490
	500
	510
2.6	520
	530
	540
	550
2.7	
	560
	570
	580
2.8	590
	600
	610
2.9	620
	630
	640
	650
3.0	660

H_A Feet	Q Sec. Ft.
3.0	660
	670
	680
3.1	690
	700
	710
	720
3.2	730
	740
	750
3.3	760
	770
	780
	790
3.4	800
	810
	820
	830
3.5	840
	850
	860
	870
3.6	880
	890
	900
	910
3.7	920
	930
	940
	950
3.8	960
	970
	980
	990
3.9	1000
	1010
	1020
	1030
4.0	1040

H_A Feet	Q Sec. Ft.
4.0	1040
	1050
	1060
	1070
4.1	1080
	1090
	1100
	1110
4.2	1120
	1130
	1140
	1150
	1160
4.3	1170
	1180
	1190
	1200
4.4	1210
	1220
	1230
	1240
4.5	1250
	1260
	1270
	1280
	1290
4.6	1300
	1310
	1320
	1330
	1340
4.7	1350
	1360
	1370
	1380
4.8	1390
	1400
	1410
	1420
	1430
4.9	1440
	1450
	1460
	1470
	1480
5.0	1490

H_A Feet	Q Sec. Ft.
5.0	1490
	1500
	1510
	1520
5.1	1530
	1540
	1550
	1560
	1570
5.2	1580
	1590
	1600
	1610
	1620
5.3	1630
	1640
	1650
	1660
	1670
5.4	1680
	1690
	1700
	1710
	1720
5.5	1730
	1740
	1750
	1760
	1770
5.6	1780
	1790
	1800
	1810
	1820
5.7	1830
	1840
	1850
	1860
	1870
5.8	1880
	1890
	1900
	1910
	1920
5.9	1930
	1940
	1950
	1960
	1970
	1980
6.0	1990

Table 25. Free-flow discharge 40-foot Parshall measuring flume.
Formula $Q=150.00\,Ha^{1.6}$

H_A Feet	Q Sec. Ft.
0.0	
.1	
.2	
	20
.3	
	25
	30
.4	35
	40
	45
.5	50
	55
	60
.6	65
	70
	75
	80
.7	85
	90
	95
	100
.8	105
	110
	115
	120
.9	125
	130
	135
	140
	145
1.0	150

H_A Feet	Q Sec. Ft.
1.0	150
	160
	170
1.1	
	180
	190
1.2	200
	210
	220
1.3	230
	240
	250
1.4	260
	270
	280
1.5	290
	300
	310
1.6	320
	330
	340
1.7	350
	360
	370
1.8	380
	390
	400
	410
1.9	420
	430
	440
	450
2.0	460

H_A Feet	Q Sec. Ft.
2.0	
	460
	470
	480
2.1	490
	500
	510
	520
2.2	530
	540
	550
	560
2.3	570
	580
	590
	600
2.4	610
	620
	630
	640
2.5	650
	660
	670
	680
2.6	690
	700
	710
	720
	730
2.7	
	740
	750
	760
	770
2.8	780
	790
	800
	810
2.9	820
	830
	840
	850
	860
3.0	870

H_A Feet	Q Sec. Ft.
3.0	870
	880
	890
	900
	910
3.1	920
	930
	940
	950
3.2	960
	970
	980
	990
	1000
3.3	1010
	1020
	1030
	1040
	1050
3.4	1060
	1070
	1080
	1090
	1100
3.5	1110
	1120
	1130
	1140
	1150
3.6	1160
	1170
	1180
	1190
	1200
	1210
3.7	1220
	1230
	1240
	1250
	1260
3.8	1270
	1280
	1290
	1300
	1310
3.9	1320
	1330
	1340
	1350
	1360
	1370
4.0	1380

H_A Feet	Q Sec. Ft.
4.0	1380
	1390
	1400
	1420
4.1	
	1440
	1460
	1480
4.2	
	1500
	1520
4.3	1540
	1560
	1580
4.4	1600
	1620
	1640
4.5	1660
	1680
	1700
4.6	1720
	1740
	1760
4.7	1780
	1800
	1820
4.8	1840
	1860
	1880
4.9	1900
	1920
	1940
	1960
5.0	1980

H_A Feet	Q Sec. Ft.
5.0	
	1980
	2000
	2020
5.1	
	2040
	2060
	2080
5.2	2100
	2120
	2140
5.3	2160
	2180
	2200
5.4	2220
	2240
	2260
	2280
5.5	2300
	2320
	2340
5.6	2360
	2380
	2400
5.7	2420
	2440
	2460
	2480
5.8	2500
	2520
	2540
5.9	2560
	2580
	2600
	2620
6.0	2640

Table 26. Free-flow discharge 50-foot Parshall measuring flume.
Formula $Q=186.88\ Ha^{1.6}$

H_A Feet	Q Sec. Ft.
0.0	
.1	
.2	
	25
.3	30
	35
	40
.4	45
	50
	55
	60
.5	65
	70
	75
	80
.6	85
	90
	95
	100
.7	105
	110
	115
	120
	125
.8	130
	135
	140
	145
	150
	155
.9	160
	165
	170
	175
	180
1.0	185
	190

H_A Feet	Q Sec. Ft.
1.0	190
	195
	200
	210
1.1	220
	230
	240
1.2	250
	260
	270
	280
1.3	290
	300
	310
1.4	320
	330
	340
	350
1.5	360
	370
	380
	390
1.6	400
	410
	420
	430
1.7	440
	450
	460
	470
1.8	480
	490
	500
	510
1.9	520
	530
	540
	550
	560
2.0	570

H_A Feet	Q Sec. Ft.
2.0	570
	580
	590
	600
2.1	610
	620
	630
	640
	650
2.2	660
	670
	680
	690
	700
2.3	710
	720
	730
	740
	750
2.4	765
	780
	795
2.5	810
	825
	840
	855
2.6	870
	885
	900
2.7	915
	930
	945
	960
2.8	975
	990
	1005
2.9	1020
	1035
	1050
	1065
3.0	1080
	1095

H_A Feet	Q Sec. Ft.
3.0	
	1095
	1110
	1125
3.1	1140
	1155
	1170
	1185
3.2	1200
	1215
	1230
	1245
3.3	1260
	1275
	1290
	1305
3.4	1320
	1335
	1350
	1365
	1380
3.5	1395
	1410
	1425
	1440
3.6	1455
	1470
	1485
	1500
3.7	1515
	1530
	1545
	1560
	1575
3.8	1590
	1605
	1620
	1635
3.9	1650
	1665
	1680
	1695
	1710
4.0	1725

H_A Feet	Q Sec. Ft.
4.0	1725
	1740
	1760
4.1	1780
	1800
	1820
	1840
4.2	1860
	1880
	1900
4.3	1920
	1940
	1960
	1980
4.4	2000
	2020
	2040
	2060
4.5	2080
	2100
	2120
	2140
4.6	2160
	2180
	2200
4.7	2220
	2240
	2260
	2280
4.8	2300
	2320
	2340
	2360
4.9	2380
	2400
	2420
	2440
5.0	2460

H_A Feet	Q Sec. Ft.
5.0	2460
	2480
	2500
	2520
5.1	2540
	2560
	2580
	2600
5.2	2620
	2640
	2660
	2680
5.3	2700
	2720
	2740
	2760
5.4	2780
	2800
	2820
	2840
5.5	2860
	2880
	2900
	2920
5.6	2940
	2960
	2980
	3000
5.7	3020
	3040
	3060
	3080
	3100
5.8	3120
	3140
	3160
	3180
5.9	3200
	3220
	3240
	3260
6.0	3280
	3300

Table 27. Discharge of standard submerged rectangular orifices in second-feet computed from the formula
$Q=0.61\sqrt{2gH}\,A$.

Head *H*, feet	Cross-sectional area A of orifice, square feet							
	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0
0.01	0.122	0.245	0.367	0.489	0.611	0.734	0.856	0.978
.02	.173	.346	.518	.691	.864	1.037	1.210	1.382
.03	.212	.424	.635	.847	1.059	1.271	1.483	1.694
.04	.245	.489	.734	.978	1.223	1.468	1.712	1.957
.05	.273	.547	.820	1.093	1.367	1.640	1.913	2.186
.06	.300	.599	.899	1.198	1.497	1.797	2.097	2.396
.07	.324	.647	.971	1.294	1.617	1.941	2.265	2.588
.08	.346	.691	1.037	1.383	1.729	2.074	2.420	2.766
.09	.367	.734	1.101	1.468	1.835	2.201	2.638	2.935
.10	.387	.773	1.160	1.557	1.933	2.320	2.707	3.094
.11	.406	.811	1.217	1.622	2.027	2.433	2.839	3.244
.12	.424	.847	1.271	1.694	2.118	2.542	2.965	3.389
.13	.441	.882	1.323	1.764	2.205	2.645	3.086	3.527
.14	.458	.915	1.373	1.830	2.287	2.745	3.203	3.660
.15	.474	.947	1.421	1.895	2.369	2.842	3.316	3.790
.16	.489	.978	1.467	1.956	2.445	2.934	3.423	3.912
.17	.504	1.008	1.512	2.016	2.520	3.024	3.528	4.032
.18	.519	1.037	1.556	2.075	2.593	3.112	3.631	4.150
.19	.533	1.066	1.599	2.132	2.665	3.198	3.731	4.264
.20	.547	1.094	1.641	2.188	2.735	3.282	3.829	4.376
.21	.561	1.120	1.681	2.241	2.801	3.361	3.921	4.482
.22	.574	1.148	1.722	2.296	2.870	3.464	4.018	4.592
.23	.587	1.172	1.758	2.345	2.931	3.517	4.103	4.690
.24	.600	1.198	1.797	2.396	2.995	3.590	4.193	4.792
.25	.612	1.223	1.834	2.446	3.057	3.668	4.280	4.891
.26	.624	1.247	1.871	2.494	3.117	3.741	4.365	4.988
.27	.636	1.270	1.906	2.541	3.176	3.811	4.446	5.082
.28	.646	1.294	1.942	2.589	3.236	3.883	4.530	5.178
.29	.659	1.319	1.978	2.638	3.297	3.956	4.616	5.276
.30	.670	1.339	2.009	2.678	3.347	4.017	4.687	5.356
.31	.681	1.363	2.045	2.726	3.407	4.089	4.771	5.452
.32	.692	1.382	2.073	2.764	3.455	4.146	4.837	5.528
.33	.703	1.405	2.107	2.810	3.513	4.215	4.917	5.620
.34	.713	1.426	2.139	2.852	3.565	4.278	4.991	5.704
.35	.724	1.446	2.169	2.892	3.615	4.338	5.061	5.784
.36	.734	1.467	2.201	2.934	3.667	4.401	5.135	5.868
.37	.745	1.488	2.232	2.976	3.720	4.464	5.208	5.952
.38	.754	1.508	2.262	3.016	3.770	4.524	5.278	6.032
.39	.764	1.527	2.291	3.054	3.818	4.582	5.345	6.109
.40	.774	1.547	2.321	3.094	3.867	4.641	5.415	6.188
.41	.783	1.567	2.350	3.133	3.917	4.700	5.483	6.266
.42	.792	1.585	2.377	3.170	3.962	4.754	5.547	6.339
.43	.802	1.604	2.406	3.208	4.010	4.812	5.614	6.416
.44	.811	1.622	2.433	3.244	4.055	4.866	5.677	6.488
.45	.820	1.640	2.461	3.281	4.101	4.921	5.741	6.562
.46	.829	1.659	2.489	3.318	4.147	4.977	5.807	6.636
.47	.839	1.678	2.517	3.356	4.195	5.035	5.874	6.713
.48	.847	1.695	2.542	3.389	4.237	5.084	5.931	6.778
.49	.856	1.712	2.568	3.424	4.280	5.136	5.992	6.848
.50	.865	1.729	2.594	3.458	4.323	5.188	6.052	6.917

Table [illegible]. Discharge of standard submerged rectangular orifices in second-feet computed from the formula $Q=0.61\sqrt{2gH}\,A$ (Cont'd).

Head H, feet	Crosssectional area A of orifice, square feet							
	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0
0.51	0.873	1.746	2.620	3.493	4.366	5.239	6.112	6.986
.52	.882	1.763	2.645	3.527	4.409	5.290	6.172	7.054
.53	.890	1.780	2.670	3.560	4.451	5.341	6.231	7.121
.54	.898	1.797	2.695	3.593	4.491	5.390	6.288	7.186
.55	.907	1.813	2.719	3.626	4.533	5.439	6.345	7.252
.56	.915	1.830	2.745	3.660	4.575	5.490	6.405	7.320
.57	.923	1.846	2.769	3.692	4.615	5.538	6.461	7.384
.58	.931	1.862	2.794	3.725	4.656	5.587	6.518	7.450
.59	.939	1.879	2.818	3.757	4.697	5.636	6.575	7.514
.60	.947	1.895	2.842	3.790	4.737	5.684	6.632	7.579
.61	.955	1.910	2.865	3.820	4.775	5.730	6.685	7.640
.62	.963	1.925	2.887	3.850	4.812	5.775	6.737	7.700
.63	.971	1.941	2.911	3.882	4.853	5.823	6.793	7.764
.64	.978	1.956	2.934	3.912	4.890	5.868	6.846	7.824
.65	.986	1.972	2.958	3.944	4.930	5.916	6.902	7.888
.66	.993	1.987	2.980	3.974	4.967	5.960	6.954	7.947
.67	1.001	2.002	3.003	4.004	5.005	6.006	7.007	8.008
.68	1.008	2.016	3.024	4.032	5.040	6.048	7.056	8.064
.69	1.016	2.032	3.048	4.064	5.080	6.096	7.112	8.128
.70	1.023	2.046	3.069	4.092	5.115	6.138	7.161	8.184
.71	1.031	2.062	3.093	4.124	5.155	6.186	7.217	8.248
.72	1.038	2.076	3.114	4.152	5.190	6.228	7.266	8.304
.73	1.045	2.090	3.135	4.180	5.225	6.270	7.315	8.360
.74	1.052	2.104	3.158	4.210	5.260	6.311	7.369	8.421
.75	1.059	2.118	3.178	4.237	5.296	6.355	7.413	8.475
.76	1.066	2.132	3.198	4.264	5.330	6.396	7.462	8.528
.77	1.072	2.145	3.217	4.290	5.362	6.434	7.507	8.579
.78	1.080	2.160	3.240	4.320	5.400	6.480	7.560	8.640
.79	1.087	2.174	3.261	4.348	5.435	6.522	7.609	8.696
.80	1.094	2.188	3.282	4.376	5.470	6.564	7.658	8.752

179

Table 29. Coefficients C to be applied to a discharge given by Table 27 to give the discharge of the same orifice suppressed, computed from the formula C=1+0.15r.

Size of orifice			Bottom suppressed		Bottom and sides suppressed	
d, feet	*l*, feet	*A* square feet	*r*	*C*	*r*	*C*
0.25	1.0	0.25	0.40	1.06	0.60	1.09
.25	2.0	.50	.44	1.07	.56	1.08
.25	3.0	.75	.46	1.07	.54	1.08
.5	1.0	.50	.33	1.05	.67	1.10
.5	1.5	.75	.37	1.06	.63	1.09
.5	2.0	1.00	.40	1.06	.60	1.09
.5	2.5	1.25	.42	1.06	.58	1.09
.5	3.0	1.50	.43	1.06	.57	1.09
.75	1.33	1.00	.32	1.05	.68	1.10
.75	1.67	1.25	.34	1.05	.66	1.10
.75	2.00	1.50	.36	1.05	.64	1.10
.75	2.33	1.75	.38	1.06	.62	1.09
.75	2.67	2.00	.39	1.06	.61	1.09

Table 37 - Convenient Equivalents

LENGTH

1 inch = 1/12 foot = .027778 yard = .000015783 mile = 2.54 centimeters.
1 foot = 12 inches = 1/3 yard = .00018939 mile = .3048 meter.
1 yard = 36 inches = 3 feet = .00056818 mile = .9144 meter.
1 mile = 63360 inches = 5280 feet = 1760 yards = 1.60935 kilometers.
1 meter = 100 centimeters = .001 kilometer = 39.37 inches = 3.2808 feet = 1.0936 yards = .00062137 mile.

SURFACE

1 square inch = .006944 square foot = .0007716 square yard = .0000001594 acre = .0000000002491 square mile = 6.45163 square centimeters.
1 square foot = 144 square inches = 1/9 square yard = .000022957 acre = .00000003587 square mile = .092903 square meters.
1 square yard = 1296 square inches = 9 square feet = .0002066 acre = .0000003228 square mile = .83613 square meter.
1 acre = 6272640 square inches = 43560 square feet = 4840 square yards = .0015625 square mile = 208.71 feet square = .404687 hectare.
1 square mile = 4014489600 square inches = 27878400 square feet = 3097600 square yards = 640 acres = 259 hectares.
1 square meter = 10000 square centimeters = .0001 hectare = .000001 square kilometer = 1550.00 square inches = 10.7639 square feet = 1.19598 square yards = .0002471 acre = .0000003861 square mile.

VOLUME

1 cubic inch = .004329 U. S. gallon = .0005787 cubic foot = 16.3872 cubic centimeters.
1 U. S. gallon = 231 cubic inches = .13368 cubic foot = .00000307 acre-foot = 3.78543 liters.
1 cubic foot = 1728 cubic inches = 7.4805 U. S. gallons = .037037 cubic yard = .000022957 acre-foot = 28.317 liters.
1 cubic yard = 46656 cubic inches = 27 cubic feet = .00061983 acre-foot = .76456 cubic meter.
1 acre-foot = 325851 U. S. gallons = 43560 cubic feet = 1613 1/3 cubic yards = 1233.49 cubic meters.
1 cubic meter, stere or kiloliter = 1000000 cubic centimeters = 1000 liters = 61023.4 cubic inches = 264.17 U. S. gallons = 35.3145 cubic feet = 1.30794 cubic yards = .000810708 acre-foot.

HYDRAULICS

1 U. S. gallon of water weighs 8.34 pounds avoirdupois.
1 cubic foot of water weighs 62.4 pounds avoirdupois.
1 second-foot = 448.8 U. S. gallons per minute = 26929.9 U. S. gallons per hour = 646317 U. S. gallons per day.
= 60 cubic feet per minute = 3600 cubic feet per hour = 86400 cubic feet per day = 31536000 cubic feet per year = .000214 cubic miles per year.
= .9917 acre-inch per hour = 1.9835 acre-feet per day = 723.9669 acre-feet per year.
= 50 miner's inches in Idaho, Kansas, Nebraska, New Mexico, North Dakota, and South Dakota = 40 miner's inches in Arizona, California, Montana, and Oregon = 38.4 miner's inches in Colorado.
= .028317 cubic meters per second = 1.699 cubic meters per minute = 101.941 cubic meters per hour = 2446.58 cubic meters per day.
1 cubic meter per minute = .5886 second-feet = 4.403 U. S. gallons per second = 1.1674 acre-feet per day.
1 million gallons per day = 1.55 second-feet = 3.07 acre-feet per day = 2.629 cubic meters per minute.
1 second-foot falling 8.81 feet = 1 horsepower.
1 second-foot falling 10 feet = 1.135 horsepower.
1 second-foot falling 11 feet = 1 horsepower, 80 per cent efficiency.
1 second-foot for 1 year will cover 1 square mile 1.131 feet or 13.572 inches deep.
1 inch deep on 1 square mile = 2323200 cubic feet = .0737 second-feet for 1 year.

Table 37 - Convenient Equivalents (Cont.)

MISCELLANEOUS

1 foot per second = .68 mile per hour = 1.097 kilometers per hour.
1 avoirdupois pound = 7000 grains = .4536 kilogram.
1 kilogram = 1000 grams = .001 tonne = 15432 grains = 2.2046 pounds avoirdupois.

1 atmosphere = about { 15 pounds per square inch.
1 ton per square foot.
1 kilogram per square centimeter. }

Acceleration of gravity, g, = 32.16 feet per second.
1 mil = .001 inch.

1 circular mil = $\frac{\pi}{4}$ $(.001)^2$ or .0000007854 square inch.

1 square inch = 1273240 circular mils.
No. 10 Birmingham gage wire has a diameter of 134 mils and a cross-sectional area of 17956 circular mils.
1 horsepower = 5694120 foot-gallons per day = 550 foot-pounds per second = 33000 foot-pounds per minute = 1980000 foot-pounds per hour = 2545 B. T. U. per hour = 76 kilogrammeters per second = 1.27 kilogrammeters per minute = 746 watts.
1 horsepower, boiler rating, requires the evaporation of 34½ pounds per hour of water at 212 degrees Fahrenheit to dry steam at the same temperature; or the expenditure of 33317 B.T.U.; and in practice is developed by burning 3½ to 4¾ pounds per hour of coal under 10 to 12 square feet of heating surface.
1 B.T.U. = 778 foot-pounds.
1 pound of bituminous coal contains about 14100 B.T.U. or 11000000 foot-pounds of energy.

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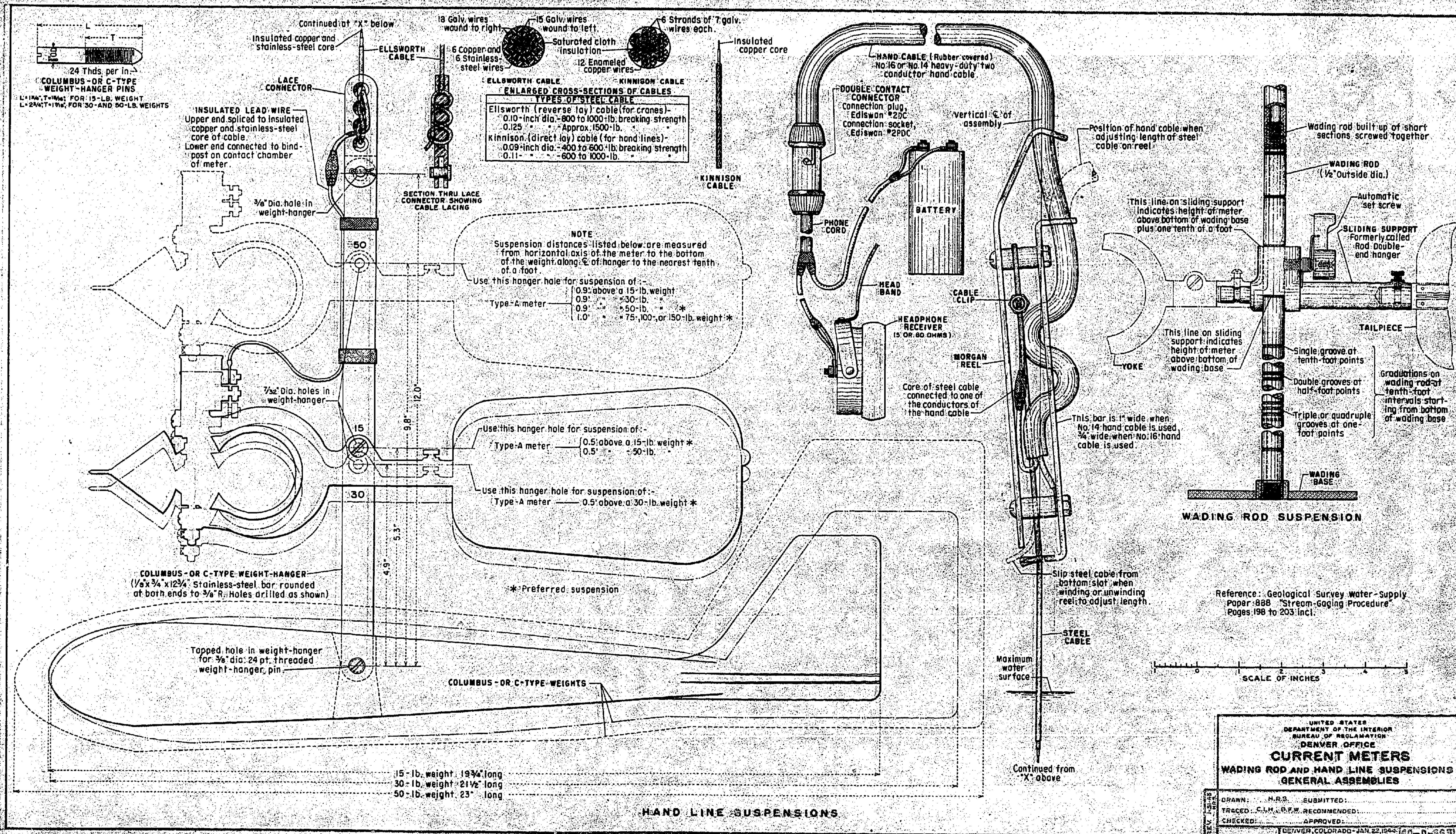
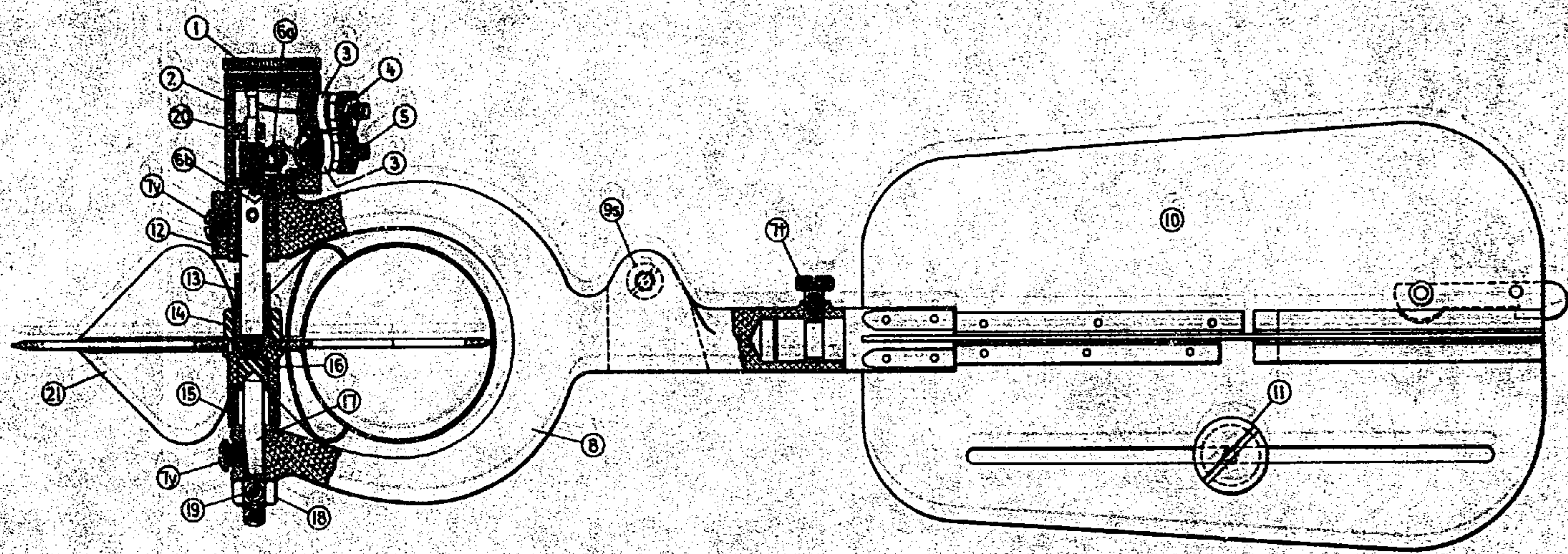
APPENDIX



Continued at "X" below
Insulated copper and stainless-steel core
ELLSWORTH CABLE
LACE CONNECTOR
24 Thds. per in.
COLUMBUS - OR C-TYPE WEIGHT - HANGER PINS
L=1¾", T=1⅜": FOR 15-LB. WEIGHT
L=2¾", T=1⅞": FOR 30- AND 50-LB. WEIGHTS
INSULATED LEAD WIRE
Upper end spliced to insulated copper and stainless-steel core of cable.
Lower end connected to bind-post on contact chamber of meter.
⅜" Dia. hole in weight-hanger
7/32" Dia. holes in weight-hanger
18 Galv. wires wound to right
15 Galv. wires wound to left
6 Copper and 6 Stainless-steel wires
Saturated cloth insulation
12 Enameled copper wires
6 Strands of 7 galv. wires each.
ELLSWORTH CABLE
KINNISON CABLE
ENLARGED CROSS-SECTIONS OF CABLES
TYPES OF STEEL CABLE
Ellsworth (reverse lay) cable (for cranes)-
0.10-inch dia.-800 to 1000-lb. breaking strength
0.125 " " Approx. 1500-lb. " "
Kinnison (direct lay) cable (for hand lines)-
0.09-inch dia.-400 to 600-lb. breaking strength
0.11- " " -600 to 1000-lb. " "
Insulated copper core
KINNISON CABLE
SECTION THRU LACE CONNECTOR SHOWING CABLE LACING
NOTE
Suspension distances listed below are measured from horizontal axis of the meter to the bottom of the weight along ℄ of hanger to the nearest tenth of a foot.
Use this hanger hole for suspension of:-
Type-A meter
0.9' above a 15-lb. weight
0.9' " " 30-lb. "
0.9' " " 50-lb. " *
1.0' " " 75-, 100-, or 150-lb. weight *
Use this hanger hole for suspension of:-
Type-A meter
0.5' above a 15-lb. weight *
0.5' " " 50-lb. "
Use this hanger hole for suspension of:-
Type-A meter
0.5' above a 30-lb. weight *
50
15
30
12.0"
9.8"
5.3"
4.9"
COLUMBUS - OR C-TYPE WEIGHT-HANGER
(⅛"x¾"x12¾" Stainless-steel bar rounded at both ends to ⅜" R. Holes drilled as shown)
* Preferred suspension
Tapped hole in weight-hanger for ⅜" dia. 24 pt. threaded weight-hanger pin
COLUMBUS - OR C-TYPE WEIGHTS
15 - lb. weight 19¾" long
30 - lb. weight 21½" long
50 - lb. weight 23" long
HAND LINE SUSPENSIONS
HAND CABLE (Rubber covered)
No.16 or No.14 heavy-duty two conductor hand cable.
DOUBLE CONTACT CONNECTOR
Connection plug, Ediswan #2DC
Connection socket, Ediswan #2PDC
PHONE CORD
BATTERY
HEAD BAND
HEADPHONE RECEIVER (5 OR 60 OHMS)
Vertical ℄ of assembly
Position of hand cable when adjusting length of steel cable on reel
CABLE CLIP
MORGAN REEL
Core of steel cable connected to one of the conductors of the hand cable
This bar is 1" wide when No.14 hand cable is used, ¾" wide when No.16 hand cable is used.
Slip steel cable from bottom slot when winding or unwinding reel to adjust length.
STEEL CABLE
Maximum water surface
Continued from "X" above
Wading rod built up of short sections screwed together
WADING ROD (½" Outside dia.)
Automatic set screw
This line on sliding support indicates height of meter above bottom of wading base plus one tenth of a foot
SLIDING SUPPORT Formerly called Rod Double-end hanger
TAILPIECE
YOKE
This line on sliding support indicates height of meter above bottom of wading base
Single groove at tenth-foot points
Double grooves at half-foot points
Triple or quadruple grooves at one-foot points
Graduations on wading rod at tenth-foot intervals starting from bottom of wading base
WADING BASE
WADING ROD SUSPENSION
Reference: Geological Survey Water-Supply Paper 888 "Stream-Gaging Procedure" Pages 198 to 203 incl.
SCALE OF INCHES
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
DENVER OFFICE
CURRENT METERS
WADING ROD AND HAND LINE SUSPENSIONS
GENERAL ASSEMBLIES
DRAWN: H.R.S. SUBMITTED:
TRACED: C.L.H. - D.F.W. RECOMMENDED:
CHECKED: APPROVED:
DENVER, COLORADO - JAN. 22, 1944
40-D-3631

Figure 30



ASSEMBLY

LIST OF PARTS

- 2a / 1 Cap for contact chamber
- 2 Contact chamber (Includes bearing lug 20)
- 5a / 4a / 4 Single-contact binding post with contact and nut
- 3 Insulating bushing for contact binding posts
- 5 Penta-contact binding post with contact and nut
- 6 / 6a Penta gear complete with shaft
- 6b Penta gear pad with pad screw
- 20 Bearing lug
- 8a / 8 Yoke
- 7t Set screw for tailpiece
- 7y Set screw for yoke
- 9s Hanger screw
- 10a / 10 Tailpiece
- 11 Balance weight
- 12 Shaft
- 13a / 13 Bucket-wheel hub (Includes pivot bearing 16)
- 14 Bucket-wheel hub nut
- 15 Raising nut
- 16 Pivot bearing
- 17a / 17 Pivot
- 18a / 18 Pivot adjusting nut
- 19 Keeper screw for pivot adjusting nut
- 21 Bucket wheel

TYPE A CURRENT METER

SHEET 1 OF 6

Figure 31

FIGURE 2

188 END