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STATE ENGINEER'S OFFICE
CARSON CITY, NEVADA

Common Methods of Measuring Water As Practiced In Western States

State Engineer

CARSON CITY, NEVADA
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COMMON METHODS OF MEASURING WATER AS PRACTICED IN THE WESTERN STATES

This pamphlet has been prepared mainly for the purpose of describing the measurement of water through the various types of weirs, orifices, and the Parshall flume. In addition to this, and in order to make the pamphlet more valuable for the engineer and water commissioner, we have briefly included the measurement of water by means of the current meter, the float and slope methods, and the establishment and use of gaging stations.

Measuring water usually means measuring the amount of water that passes a given point in a given time. In other words, the flow of a stream expressed in cubic feet per second (*i. e.*, c.f.s. = 448.83 gallons per minute), is the result of multiplying the cross-sectional area in square feet by the average velocity in feet per second. For example, if at a certain point on a stream it has been determined that the area of a section at right angles to the line of flow is four (4) square feet, and the average velocity has been determined to be 3.0 feet per second, the flow of the stream would then be

3.0 (velocity in feet per second) × 4.0 (cross-section area in square feet) = 12.0 c.f.s. (cubic feet per second).

UNITS OF MEASURE

The present-day unit of measurement is cubic feet per second. In all formulas and tables in this bulletin the unit of measurement of water is cubic feet per second.

Prior to recent times the unit of measurement in most western States was the miner's inch. The miner's inch is the quantity of water flowing in a certain time through an orifice one inch square under a specified head. In Nevada the miner's inch has a head of about 6¼ inches. Both the dimensions and the head vary in different States, and it therefore is an arbitrary unit. The amount of water represented by a miner's inch in Nevada is 0.025 c.f.s. (cubic foot per second), or 11.22 gallons per minute. Forty miner's inches by statute is equivalent to a cubic foot per second. The same unit is statutory in northern California, Arizona, Oregon, and Montana. The Utah statute inch is the flow of water through an orifice with an area of one square inch under a head of four inches—approximately $\frac{1}{50}$ of a cubic foot per second. This unit is the statutory miner's inch in Idaho, New Mexico, and Washington, and is commonly used in southern California. Being so ambiguous, this unit of measurement is not satisfactory, and has been practically replaced by the cubic foot per second unit.

MEASUREMENTS OF DISCHARGE

The methods ordinarily used for determining the quantity of water flowing in open channels are of two kinds—the velocity-area method and the weir method. In the former the quantity of discharge is obtained as a summation of the products of partial areas of the cross-section of the stream by the respective measured velocities in such areas, and involves the measurement of cross-sectional areas and velocities of the flowing water. The cross-sectional areas are obtained by measurement of the width and depth at points so spaced as to show the shape of the cross-section or bed of the stream. Velocities may be measured by slope, float or current meter, each involving a fundamentally distinct process.

The weir method involves the use of a formula which contains three factors—area of cross-section, velocity, and a coefficient varying with the type of weir. In this type the discharge is computed by a formula, or obtained from tables computed by a formula, from the observed "head" on the weir and the known dimensions of the weir.

DETERMINATION OF FLOW BY FLOATS

Where it is desired to obtain an approximate measure of the flow of a stream and where conditions do not warrant the installation of any of the measuring devices described in the following chapters, such a measurement can be made by means of the "float method."

The usual procedure in determining rate of discharge by using the float method is first to select a straight course along the stream, which should be from fifty to two hundred feet in length, although fairly good results can be obtained from shorter courses. Stretch a tape or string, or else lay a stick, across the stream at right angles to the direction of flow at both the upper and lower stations on the measuring course at a known distance apart. Then place a float in the stream a few feet above the upper station and get the time, by means of a watch or stop watch, that is required for the float to pass between the two measuring points. Several measurements should be made with the float at different parts of the stream. The length of the course divided by the average time in seconds it requires the float to traverse the course gives the observed mean velocity in feet per second.

Since the velocity of water varies from the surface down and between the sides of the stream, it is necessary to apply a coefficient of reduction. Usually for surface floats the coefficient is taken as being 0.80. Then to get the mean velocity the observed velocity must be multiplied by this coefficient.

A lemon makes a good float, although any small object, such as a block of wood, a tin can weighted with sand, a long-necked bottle partly filled with water and corked, whose specific gravity can be made nearly equal to that of water, but which exposes a surface easily seen, makes a good surface float.

The next step is to get the mean cross-sectional area of the two stations. The area of each station can be obtained by multiplying the width by the average depth, and the mean cross-sectional area of the course is the average of areas at the two stations.

Example 1. Two stations on a small creek are 60 feet apart and the average time it took the float to traverse between the two stations was found to be 40 seconds. Using a coefficient of 0.80, determine the mean velocity of the creek.

Solution. The observed velocity is the course distance divided by the time in seconds, which is $60 \div 40 = 1.5$ feet per second. The mean velocity is then obtained by multiplying by the coefficient of reduction, *i. e.*, $1.5 \times 0.80 = 1.2$ feet per second.

Example 2. Using the mean velocity of 1.2 feet per second as determined in the preceding example, determine the discharge when the width of the creek at the upper station is 3.0 and the average depth is 0.7 feet, and at the lower station the width is 3.5 and the average depth is 0.5 feet.

Solution. The cross-section area at the upper station is $0.7 \times 3.0 = 2.1$ square feet. At the lower station the area is $0.5 \times 3.5 = 1.75$ square feet. The mean cross-sectional area is then $2.1 + 1.75 \div 2 = 1.92$ square feet.

From the preceding example the mean velocity is 1.2 feet per second. The discharge is then 1.2 (velocity) $\times$ 1.92 (area) $=$ 2.30 cubic feet per second (c.f.s.).

Where the creek or stream to be measured is wide enough so that the float could be floated down in different positions in relation to the width, then the creek between the stations could be divided into sections, the discharge of each section obtained separately, and the sum of the several sections would be the discharge. This is necessary for good measurements, because the velocity of the water varies in accordance with the distance from the banks, the highest velocity being near the center of the creek. It is readily seen, then, that if just one float measurement was taken down the middle of the stream the recorded velocity would be above the mean velocity, and the computed discharge too high.

However, in many Nevada streams the width is so narrow that it is only possible to get the one float measurement near the middle of the creek, in which case the computed velocity is too high and allowances should be made. After all, the float method of measuring water is only approximate, and in all cases where accurate results are necessary the weir, orifice or current meter methods described in this pamphlet should be used.

METHODS OF MEASUREMENT

Irrigation water is usually measured by one of four methods, over a weir, through an orifice, through a Parshall Measuring Flume (Improved Venturi Flume), or in an open channel. The weir, being the most generally used, will be treated first.

A weir may be described as a structure containing a notch of fixed dimensions through which water may flow when placed according to certain rules in a stream. Certain types of weirs are classified according to the shape of the notch, and those in most common use are the V-notch weir, also known as the ninety-degree triangular notch weir, the rectangular weir, the Cippoletti weir, and the rectangular suppressed weir.

In this article "weirs" will be restricted to sharp-crested weirs of the above types. Contracted weirs are those wherein the notch over which the water flows is narrower and shallower than the channel through which the water flows and have sharp upstream corners or edges on both the crest and sides of the notch, so formed that the water

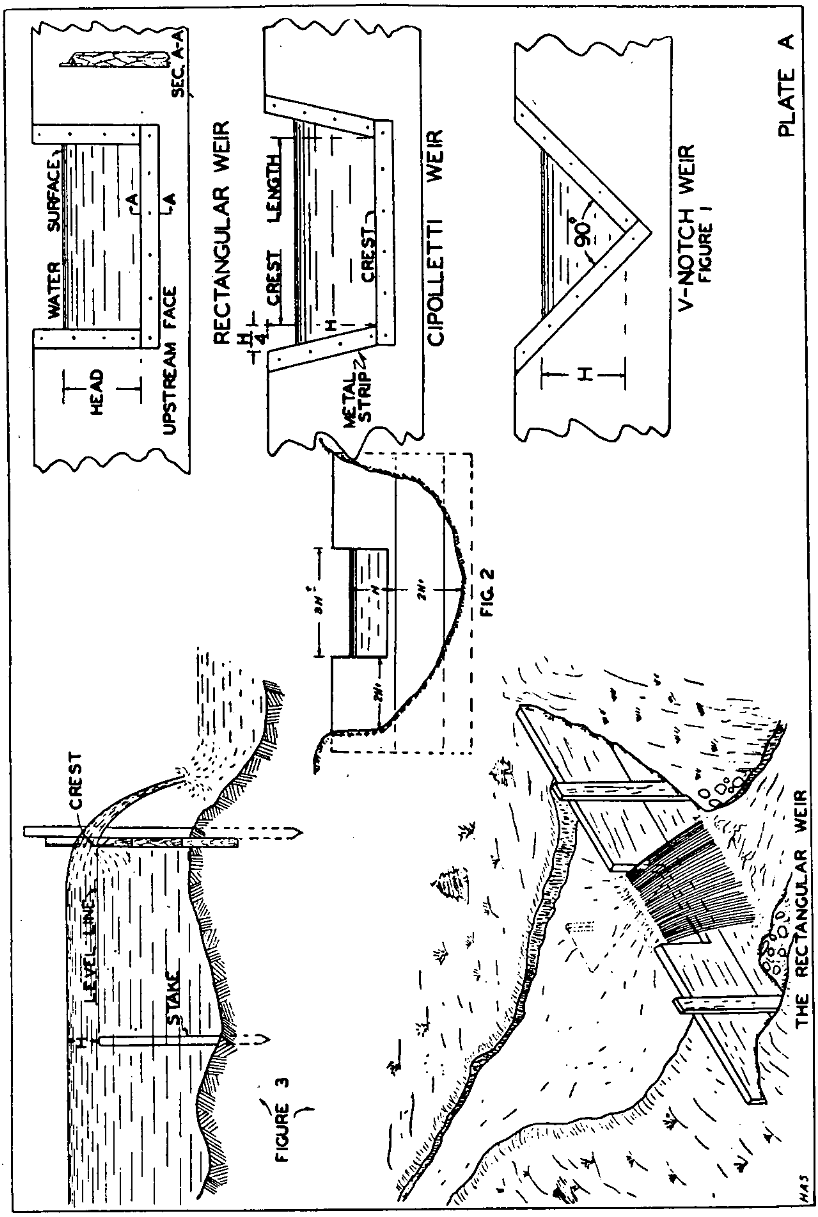
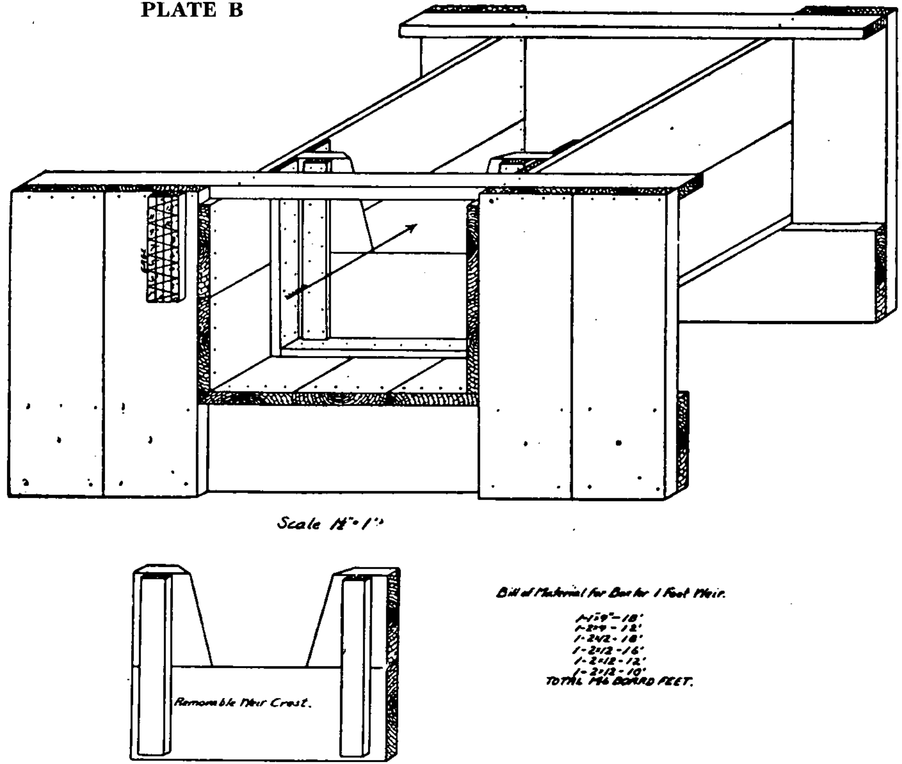

WATER SURFACE
HEAD
UPSTREAM FACE
A
A
SEC. A-A
RECTANGULAR WEIR
H/4
CREST
CREST LENGTH
H
CREST
METAL STRIP
CIPOLLETTI WEIR
H
90°
V-NOTCH WEIR
FIGURE I
PLATE A
3H
H
2H
2H
FIG. 2
CREST
LEVEL LINE
H
STAKE
FIGURE 3
THE RECTANGULAR WEIR
HAS

PLATE B



CIPPOLETTI WEIR AND BOX.

springs clear and does not adhere to the sides of the notch. In other words, as the water presses through the notch it comes in contact with only the upstream edge of the notch. Suppressed weirs are those wherein the notch is as wide as the channel leading to it, and consequently the issuing stream is not contracted at the sides, but at the bottom only. This type of weir is recognized as giving the most accurate measurements, but is not in general use in Nevada. It will be discussed later in this pamphlet.

The weir, when properly constructed and installed, is one of the simplest and most accurate methods of measuring water. It is easily and cheaply constructed, and may be installed by the layman by following the simple instructions given herein, and under ideal conditions accuracy can be obtained to within two or three percent.

The three types of contracted weirs are shown in Figure 1, Plate A, and it matters little which one is used. It is generally agreed upon by engineers that for measuring small flows the V-notch weir is the most accurate—that is, for flows of one cubic foot per second or less, and for the larger flows from one cubic foot per second to ten cubic feet per second, it is as accurate as any other type, although for the larger flows it is not generally used because, due to its smaller opening, the water backs up higher than for other weirs with the same discharge. Plate B shows the Cippoletti weir and box. In this structure the weir plate is removable. The rectangular, or V-notch, weir plate could be substituted.

The rectangular contracted weir under laboratory conditions is more accurate than the Cippoletti weir. However, in field use, either one will give as accurate results as the other. The rectangular weir is easier to construct, and for this reason it is recommended by the State Engineer's office.

The following rules should be adhered to as closely as possible in order to get good measurements:

1. The weir should be set in a channel that is straight for a distance upstream from the weir equal to at least ten times the length of the weir crest.
2. The weir should be placed at right angles to the stream.
3. The face of the weir structure should be perpendicular, and the weir crest straight and level. In the case of the V-notch weir the imaginary line bisecting the 90° opening should be perpendicular.
4. The weir should, if possible, be set at the lower end of a long pool sufficiently wide and deep so that the water will approach, free from eddies, at a velocity not exceeding 0.5 foot per second.
5. The crest and sides of the weir notch should not exceed one-eighth of an inch in thickness on the upstream face. When a weir is to be used for some time and is cut from wood, a metal strip having a thickness of from 1/16 to 1/8 of an inch and about 3 inches in width should be used to form the edges of the weir notch. Satisfactory weirs have been made by cutting the weir notch out of a piece of sheet metal of sufficient size to form the whole structure.
6. The height of the crest of the weir above the bottom of

the channel, upstream from the weir, should be at least twice the depth or head of the water flowing over the crest, and preferably three times the head. To maintain this condition it requires diligence in cleaning out the material that is bound to collect.

The distance from the side of the weir notch to the sides of the channel or weir box should be at least twice the depth or head of water passing over the crest.

The length of the weir crest should be such that the head to be measured should exceed two inches and the maximum head preferably not greater than one-third the length of the weir crest. Figure 2, Plate A.

7. The crest of the weir should be placed high enough so that water will fall practically free below the weir and so that air can circulate freely beneath the overflowing water.

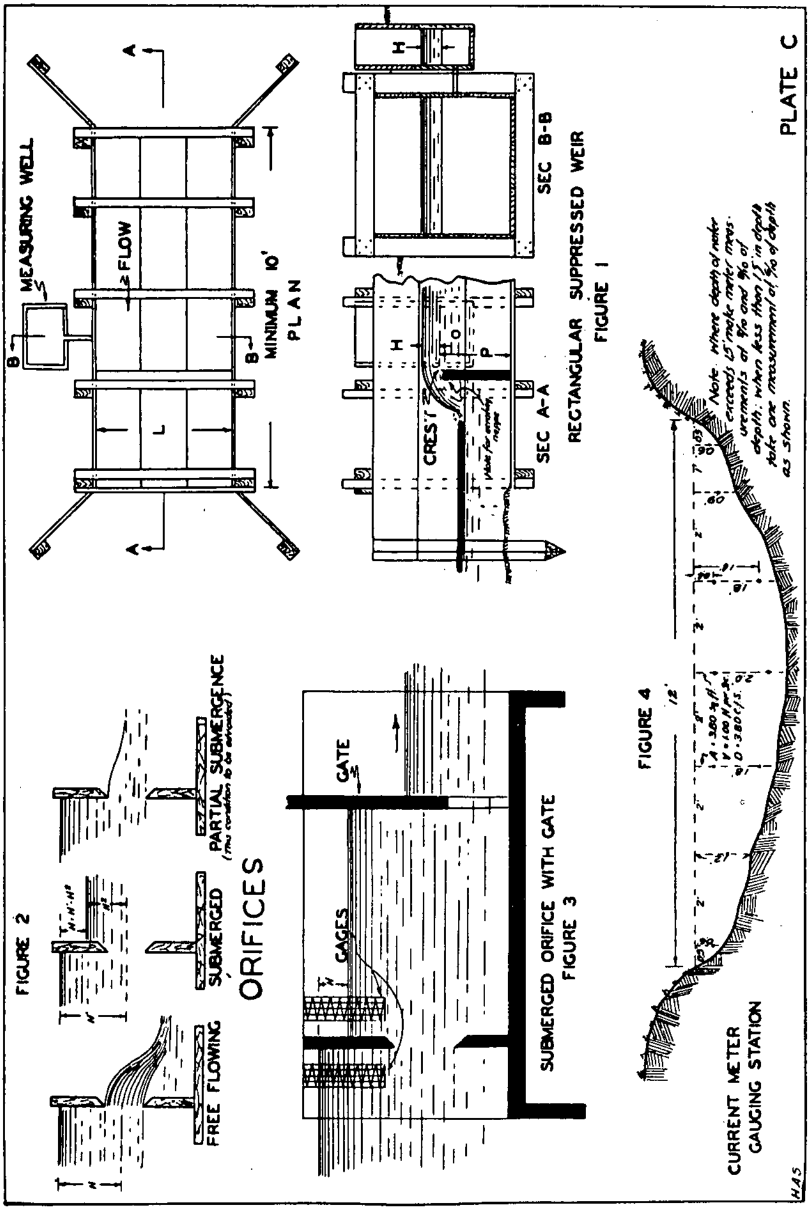
8. The depth or head of the water passing over the crest should be measured at a point where the surface curve does not affect the measurement. This may be done by placing the weir gage on the upstream face of the weir structure and far enough to one side so that it will be in comparatively still water. A simple way is to drive a nail into the upstream face of the weir structure at the exact level of the weir crest or by driving a stake in the pool at a point from two to six feet above the weir and to one side. The top of the stake should be about one-half inch below the elevation of the crest. A nail is then driven into the top of the stake so that the top of the nail is exactly level with the weir crest. In measuring the head the distance from the top of the nail to the water surface is measured by a ruler.

Figure 3, Plate A, shows the rectangular weir in operation.

RECTANGULAR SUPPRESSED WEIR

As previously explained, a suppressed weir is one that has no end contractions, having only bottom contraction. Such a weir is in the form of a flume of uniform width, with a vertical weir plate having a horizontal crest. To properly function, the flume should be long enough so that the velocities are equally distributed and should be at least ten times the length of the crest, and should be high enough to allow sufficient freeboard in case of high discharges. The depth of water or head passing over the weir should be measured at a point far enough above the weir so that the measurement is not affected by the curve produced by the falling water. This distance should be about two feet. The point measured from or the zero of the gage should be level with the crest of the weir plate. To obtain accurate results a measuring well is recommended.

To function properly, artificial ventilation should be provided under the nappe, which is the sheet of water falling over the weir. This can be accomplished by drilling a small hole on each side of the flume close to the downstream edge of the weir plate and below the weir crest. To obtain reasonable accuracy the weir plate should be vertical and the crest level. The upstream face of the weir plate should be smooth and the crest not over ⅛ inch in width, with a sharp upstream edge.


MEASURING WELL
FLOW
MINIMUM 10'
PLAN
SEC A-A
SEC B-B
CREST
RECTANGULAR SUPPRESSED WEIR
FIGURE 1
PLATE C
FIGURE 2
FREE FLOWING
SUBMERGED
PARTIAL SUBMERGENCE
(This condition to be avoided)
ORIFICES
GATE
GAGES
SUBMERGED ORIFICE WITH GATE
FIGURE 3
FIGURE 4
CURRENT METER
GAUGING STATION
H.A.S.

The length of the weir crest should be three times the average head of the water passing over it and the height of the crest above the floor of the weir structure or bottom of the channel should be at least equal to the maximum head to be measured. For good results the head measured should not be greater than 2.0 feet or smaller than 0.2 foot.

Table 4 gives discharges for weir crests of one foot for various weir heights or height of weir crest above the bottom of channel of approach. For different crest lengths multiply discharges as given for head and weir height by length of weir crest used.

Figure 1, Plate C, shows the plan of the rectangular suppressed weir. As stated above, a measuring well should be used, but accurate results can be obtained if care is used by measuring the head in the flume at a point about two feet upstream from the crest.

WEIR FORMULAS

Tables 1, 2, and 3 showing discharges over the rectangular, Cippoletti and V-notch weirs were worked out from formulas developed by "Cone." Table 4 for the rectangular suppressed weir was developed by use of Rehbock's formula. These formulas are all too complicated to have any practical value for the layman. The following formulas for discharge over weirs are convenient to use and accurate enough for all practical purposes when discharge tables cannot be used:

Rectangular weir—$Q = 3.33\ (L - 0.2\ H)\ H^{3/2}$ (Francis).
Cippoletti weir—$Q = 3.367\ L\ H^{3/2}$ (Cippoletti).
V-notch weir—$Q = 2.54\ H^{5/2}$ (Thompson).
Rectangular suppressed weir—
$Q = 3.33\ L\ H^{3/2}$ (Francis)

where H = head, L = crest length, and Q = discharge in c.f.s.

When velocity exceeds 0.5 foot per second the head which causes the velocity should be added to the measured head in using the above formulas and also when using Tables 1 and 2.

$$V^2 = 2\ gh$$

$$h = \frac{V^2}{2g} = \frac{V^2}{2 \times 32.16} = 0.0155\ V^2$$

Example. Assume that the discharge of a stream is being obtained by means of a one-foot rectangular weir and that the measured head is 0.40 foot. By means of the float method previously explained the velocity of the stream has been found to be about one foot per second.

The head used in producing this velocity can be obtained by use of the formula $h = .0155\ V^2$. In this case

$$h = 1 \times 1 \times .0155 = .0155$$

$$\text{Therefore } H = 0.4 + .015 = 0.415$$

and the discharge as given in Table 1 is 0.848 c.f.s. Using the head of 0.4 in Table 1 the discharge is given as 0.804 c.f.s., which is 0.044 c.f.s. less than obtained by taking into consideration the velocity of approach.

The velocity of approach does not have such great effect on the V-notch weir and seldom needs to be taken into consideration. Neither does the velocity of approach have to be considered in using Table 4 developed from Rehbock's formula insofar as this formula corrects for velocity of approach.

The velocity of approach is materially affected by deposits of sand and silt upstream from the weir, causing a reduced section through which the water must pass and thus increasing the velocity of approach.

It must be remembered that when the conditions for complete contraction are satisfied, that is, when the position of the weir opening is in accordance with instructions given in Figure 2, Plate A, the error in flow caused by neglecting the velocity of approach will be less than 1 percent.

ORIFICES

An orifice is an opening in a thin wall of regular form through which water flows. When the opening flows completely full and the water touches the inside opening only, it is called a standard orifice. When the opening flows only partially full the orifice becomes a weir, and the orifice discharge tables are not applicable.

Free flowing orifices are those discharging into the air and where the downstream water surface is lower than the bottom of the orifice.

Submerged orifices are those discharging under water and where the downstream water surface is above the top of the orifice.

Orifices having partial submergence are those where the downstream water surface is between the elevation of the top and bottom of the orifice. This condition must be avoided. Figure 2, Plate C, shows these three types of orifices.

In orifices the term "head" means the effective pressure that produces the flow through the orifice and is measured in feet or fractions thereof. For free-flowing orifices the head is measured as the vertical distance from the center of the orifice to the upstream water surface. For submerged orifices the effective head is the difference in elevation between the water surface on the two faces of the orifice.

The two types of orifices in general use are those of fixed dimensions which are standard orifices and the adjustable orifice headgate.

The coefficient of the orifice is the ratio of the actual to the theoretical discharge. In standard orifices with fixed dimensions, which are orifices having thin walls or with a sharp upstream edge, the coefficient is usually taken as 0.61. It varies some for different heads and sizes of opening, but for general purposes the coefficient of 0.61 will prove satisfactory. Table 5 has been prepared using a coefficient of 0.61.

The submerged orifice is a common measuring device installed and used where the channel conveying the water has not sufficient fall to permit the use of a weir, or when the waters are so heavily charged with silt that there is danger of the weir pond silting up. Being more difficult to construct, the orifice is not as generally used as the weir.

The following rules govern the use of the submerged orifice with fixed dimensions:

1. The orifice structure must have a smooth vertical face of sufficient size.
2. The orifice must be standard with sharp upstream edges.
3. The dimensions of the orifice must be known exactly.

The opening should be so constructed so as to have an area of one square foot or multiple thereof to conform to standard discharge tables. Table 5 shows discharges through rectangular orifices with fixed dimensions for any head from 0.01 to 1.50 feet for openings with areas of 0.25, 0.333, 0.50, 0.75, 1.00, 1.50, and 2.0 square feet. Where the area of the opening is other than the standard sizes as given above, the discharge may be obtained by use of Table 5 by merely multiplying the area in square feet by the discharge shown in the column headed 1.00 square foot for the head (H) being used.

4. The orifice must be of such size that the effective head is never less than 2 inches and preferably the maximum head should not exceed 6 inches, although the head can exceed this amount without any appreciable error in discharge.

5. In the installation of a standard orifice with complete contraction the distance from the bottom of the orifice to the bottom of the box or channel and from the ends of the orifice to the sides of the box or channel should be not less than twice the least dimension of the orifice.

6. Provisions must be made to measure the effective head. Since the head on a submerged orifice is the difference in water level on the upstream and downstream face of the orifice, measurements must be made at two points. The general method often used is to fasten a gage on the headwall and to one side of the orifice on both the upstream and downstream face, with the zero mark at the same elevation. The elevation of the water level is read on both gages and the difference is the effective head.

Another method is to set two stakes in the stream, one above and one below the orifice a few feet, with the tops of the stake at the same elevation. The distance from the top of the stake to the water level is measured with a rule in both places, and the difference is the effective head. The stakes should be set at a point where the water surface is fairly quiet. For accurate discharges these measurements should be exact, as a slight error in reading the gage makes a considerable error in the discharges. Table 5 gives the flow through orifices with fixed dimensions, using a coefficient of 0.61.

Plate D shows the submerged fixed orifice in conjunction with an adjustable gate. Figure 3, Plate C, shows a longitudinal section of such a structure.

The usual type of adjustable orifice is the headgate where the discharge may be either free or submerged, partial submergence being avoided. The headgate orifice has the hydraulic properties of orifices, the formula for discharge (Q) in cubic feet per second being:

$Q = a\ c\ \sqrt{2\ gH}$ where

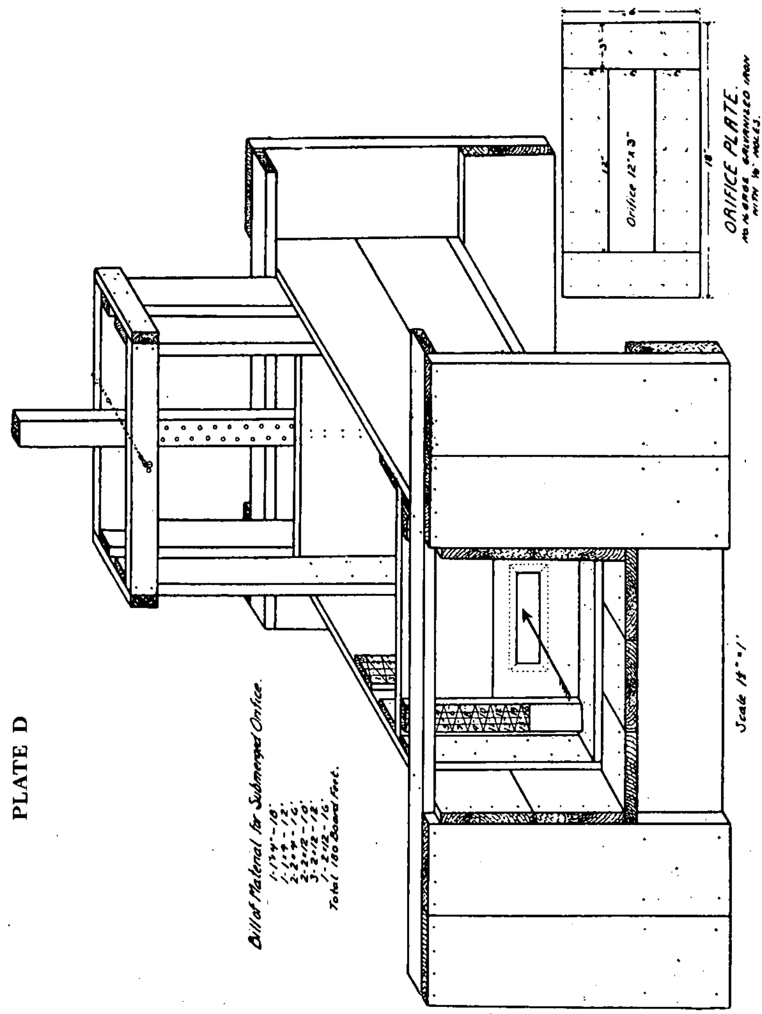
c = coefficient of discharge

a = area of opening in square feet

H = effective head = the head to the center of the orifice opening for free discharge and the difference in elevation of water surface on the two sides of the gate for submerged orifices.

g = acceleration due to gravity = 32.2

PLATE D



SUBMERGED ORIFICE AND BOX

To obtain discharge in cubic feet per second the velocity is multiplied by the area in square feet of the opening.

The coefficient of discharge in the adjustable orifice headgate varies with the size of the opening which affects the velocity of approach and also with the degree of contraction. Since these are all variable factors, the submerged orifice headgates are not accurate measuring devices. Therefore, to obtain fair accuracy of discharge the structure should be calibrated by installing a weir of some type at a suitable point below the gate, and for different openings and heads on the headgate obtain the corresponding discharge by means of the weir.

By experience it has been found that the average coefficient of discharge for the adjustable orifice headgate, where the gate guides are made from 2 x 4 inch material and a 2 x 4 or 2 x 6 inch board is set permanently on edge on the floor of the box with the ends of the groove between the gate guides, is 0.70. Where there is no bottom contraction, the coefficient varies from 0.70 to over 1.0. Table 6 gives velocities for heads from 0.01 to 4.0 feet, using the formula.

$$V = 0.70 \sqrt{2gH}$$

Problem. Find the flow through a 4-foot gate when the effective head measures 1.41 feet and the gate opening is 1.0 foot.

Solution. From Table 6 the velocity for a head of 1.41 feet is 6.68 feet per second. The area of opening is $4 \times 1.0 = 4$ square feet. Therefore, the approximate discharge is $4 \times 6.68 = 26.72$ c.f.s.

THE PARSHALL MEASURING FLUME

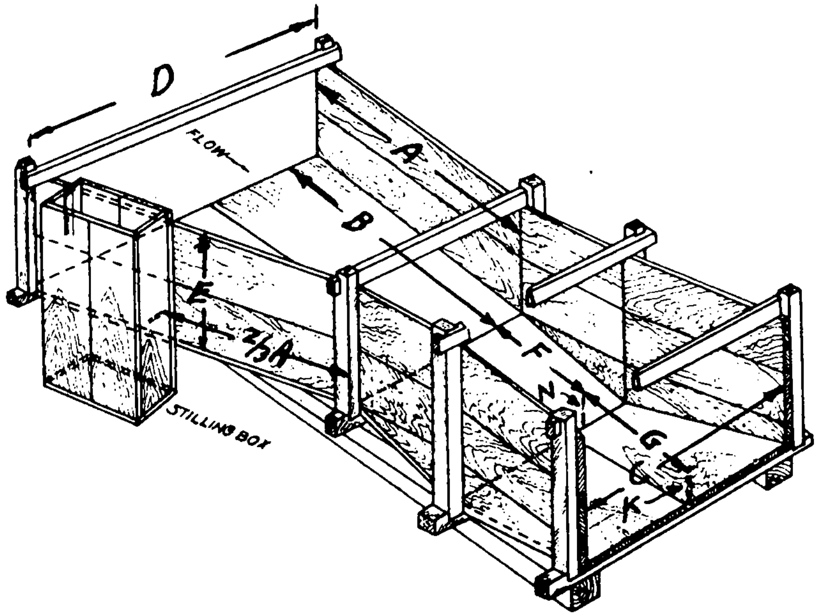
The Parshall flume was developed by the United States Department of Agriculture, cooperating with the Colorado Agricultural Experiment Station under the direction of Ralph L. Parshall. (See Plate E). The use of this type of measuring device has become widespread throughout most of the western States. During the past 10 years over 100 Parshall flumes have been placed in use in Nevada with sizes ranging from a throat width of 3 inches to 8 feet. While the flumes can be made of wood or concrete, it has been found practical to purchase them already made up of steel construction. Information can be supplied by this office as to where such flumes may be purchased.

The Parshall flume consists of a level converging section which forms the crest, a throat, and a diverging section. For throat widths of 1 to 8 feet the floor of the throat is inclined downward at a slope of 9 inches vertically to 24 inches horizontally, and the floor of the diverging or downstream section inclines upward at a slope of 6 inches vertically to 36 inches horizontally, the end of the floor at the downstream end being 3 inches lower than the crest or upstream section. For the small flumes, 3 inches, 6 inches, and 9 inches, the dimensions are different than for the larger flumes; however, the slope of the throat floor is the same for all sizes. The appropriate dimensions for flumes ranging from 3-inch throat widths up to 8 feet are shown on page 23.

The size of the Parshall flume is determined by the width of the throat section which is sometimes referred to as the "crest length."

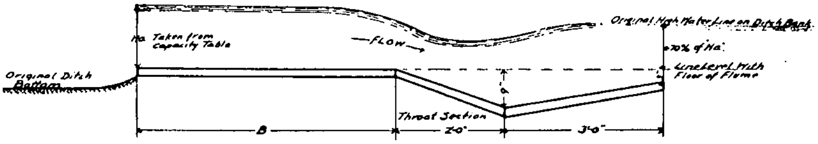
The discharge through a Parshall flume is called "free flow" when the elevation of the water surface near the downstream end of the throat section is not high enough to cause any retardation of the flow due to back water. This condition exists when the upstream floor of the flume is placed at such an elevation above the channel bottom that the difference in evelation between the water surface at the gage

PLATE E



in the converging section (Ha) and the water surface near the lower end of the throat section is greater than 40 percent of the depth of the water at the "Ha" gage for the 3-inch, 6-inch, and 9-inch flumes and greater than 30 percent "Ha" for the 1-foot and larger flumes. In other words, for the 1-foot and larger flumes the difference in elevation between the crest or floor of the converging or upstream section, and the water surface at the lower end of the throat section, should not be greater than 70 percent of the depth of water at the upstream gage, *i. e.*, 70 percent "Ha." Another way of expressing this is that the ratio of the Hb and Ha heads must not exceed 0.7 for the 1-foot and larger flumes and 0.6 for the small flumes for free-flow conditions. When there are submerged flows, it is necessary to install another gage called the "Hb" gage near the lower end of the throat section as illustrated on Plate F. Usually a stilling well must be used here. The elevation of the water at the end of the flume is about the same as at the Hb location, and can be used for determining whether or not the flow is submerged.

The following design shows the proper setting for a 1-foot and larger flume under free-flow conditions.



DIRECTIONS FOR PLACING FLUME.

DIRECTION FOR PLACING FLUME

First—Locate the high water line on ditch bank where the flume is to be installed as shown by previous flows.

Second—Select from the discharge tables the proper depth of water or head "Ha" that corresponds with the maximum discharge of ditch.

Third—Place the upstream floor of the flume at a depth of not more than 70 percent of Ha below the higher water line. This would be the same as placing the upstream floor at a distance above the bottom of the ditch obtained by deducting 70 percent of Ha from depth of water in ditch, *i. e.*, distance from bottom of ditch to high water line of ditch.

Fourth—Place the floor "B" level, both length and crosswise. Where conditions are such that the submergence is greater than 70 percent for the 1- to 8-foot flumes, which causes a back-water condition that affects the flow, it is necessary to install another gage near the bottom of the throat section with the zero of the gage at the same elevation as the zero of the upper gage, which is at the level of the crest. This will be discussed later.

It might be noted here that if careful attention is given to choosing the size of flume used, it is very seldom that a free-flow condition cannot exist. This might be further emphasized by the fact that the loss of head (that is, the difference in elevation above and below the measuring structure), required in the use of weirs is approximately four times as great as that needed for the Parshall flume where the crest length of weir and width of flume are the same.

SELECTION OF SIZE AND SETTING

The successful operation of the Parshall flume depends upon setting the crest of the flume at the proper elevation above the bed of the channel. Where the grade is fairly steep and the banks high, very little trouble is had in setting the flume, but where the banks are low above the surface of the water and the grade quite flat, too much precaution cannot be taken in choosing the size and setting of the flume.

Before constructing or purchasing the flume, first ascertain the conditions necessary to determine the size flume needed. For instance, under a certain condition a 1-foot flume might be installed in a channel where the submergence is over 70 percent, making it necessary to use two gages and correction tables, whereas with proper investigation beforehand a 2-foot flume could have been installed, resulting in a free-flow discharge. The table on page 23 gives dimensions and capacities for various flume widths (W).

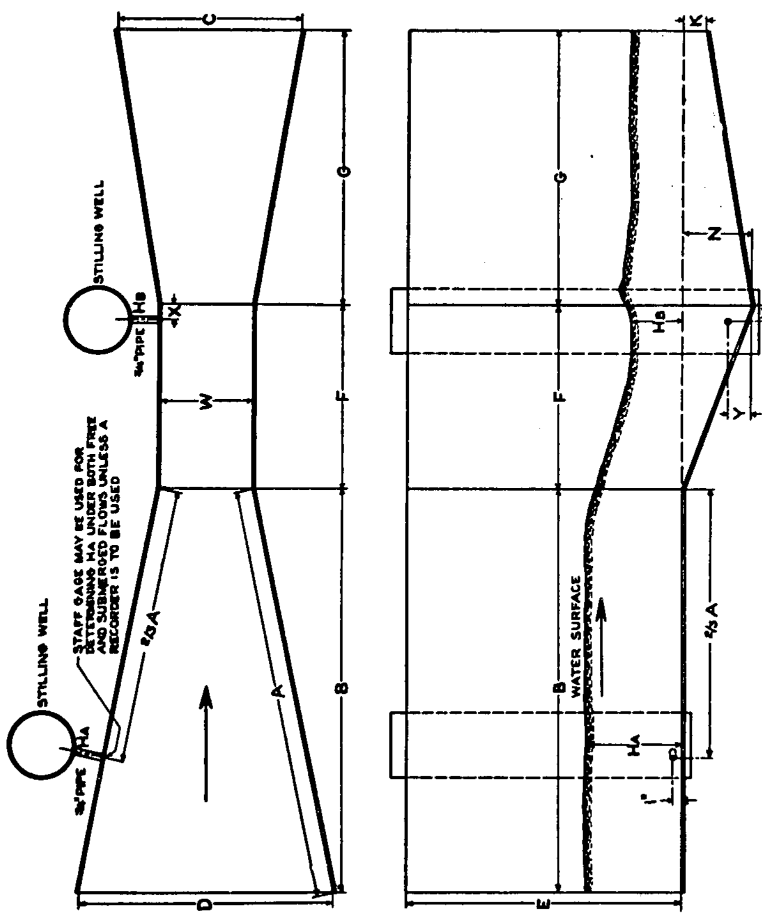
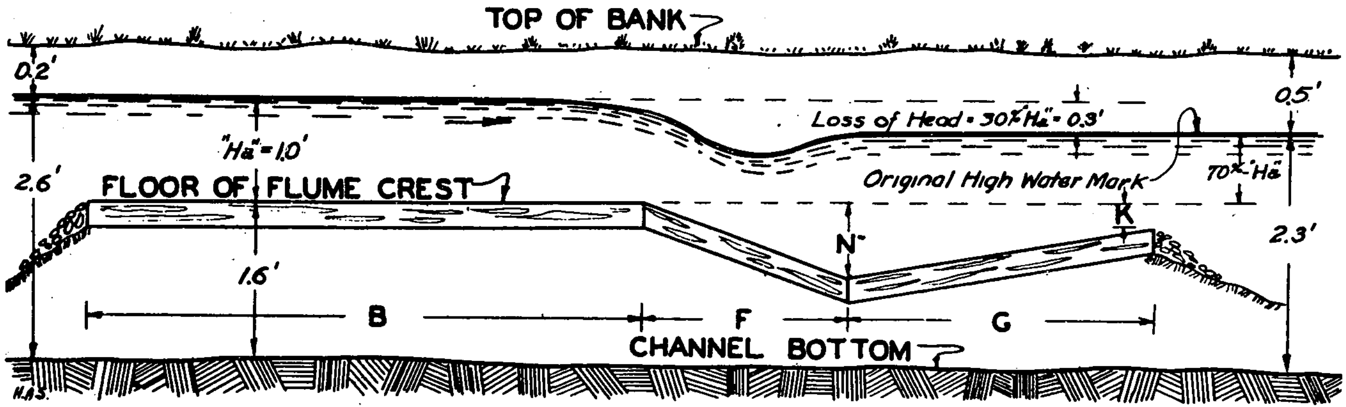


PLATE F—Plan and elevation of a Parshall measuring flume. See page 23 for actual dimensions for various sizes of flume.

Dimensions and capacities of the Parshall measuring flume, for various throat widths, W.
(Letters refer to Plate E)

W Ft.	W In.	A Ft.	A In.	2/3 A Ft.	2/3 A In.	B Ft.	B In.	C Ft.	C In.	D Ft.	D In.	E Ft.	E In.	F Ft.	F In.	G Ft.	G In.	K In.	N In.	X In.	Y In.	Free-Flow Capacity Minimum Sec.-ft.	Free-Flow Capacity Maximum Sec.-ft.
0	3	1	6⅜	1	¼	1	6	0	7	0	10 3/16	1	3	0	6	1	0	1	2¼	1	1½	0.03	0.60
0	6	2	7/16	1	4 5/16	2	0	1	3½	1	3⅝	1	6	1	0	2	0	3	4½	2	3	.05	2.9
0	9	2	10⅝	1	11⅛	2	10	1	3	1	10⅝	2	0	1	0	1	6	3	4½	2	3	.09	5.1
1	0	4	6	3	0	4	4⅞	2	0	2	9¼	3	0	2	0	3	0	3	9	2	3	0.20	16.1
1	6	4	9	3	2	4	7⅞	2	6	3	4⅜	3	0	2	0	3	0	3	9	2	3	0.30	24.6
2	0	5	0	3	4	4	10⅞	3	0	3	11½	3	0	2	0	3	0	3	9	2	3	.42	33.1
3	0	5	6	3	8	5	4¾	4	0	5	1⅞	3	0	2	0	3	0	3	9	2	3	.61	50.4
4	0	6	0	4	0	5	10⅝	5	0	6	4¼	3	0	2	0	3	0	3	9	2	3	1.3	67.9
5	0	6	6	4	4	6	4½	6	0	7	6⅝	3	0	2	0	3	0	3	9	2	3	2.2	85.6
6	0	7	0	4	8	6	10⅜	7	0	8	9	3	0	2	0	3	0	3	9	2	3	2.6	103.5
7	0	7	6	5	0	7	4¼	8	0	9	11⅜	3	0	2	0	3	0	3	9	2	3	3.0	121.4
8	0	8	0	5	4	7	10⅛	9	0	11	1¾	3	0	2	0	3	0	3	9	2	3	3.5	139.5



It has been previously stated in this discussion that for free flow the maximum submergence for a flume under 1.0 foot was 60 percent and for flumes over 1 foot in size, 70 percent. Where conditions are possible the submergence should be less in order to safeguard against higher flows than anticipated. For example, assume that a flume is to be installed in a channel where the maximum flow is about 12 c.f.s. and the water level at maximum flow 2.3 feet above the bottom of the channel and the freeboard (distance from high water to top of bank) is 6 inches. (See figure on page 23). When the flume is in operation the narrowed throat section will cause the water level above the flume to raise, while the water level below remains practically as it was originally. Since the free board is 6 inches, that means that the water under maximum flow can only be raised about 4 inches higher than the original high water mark, unless the upstream banks can be raised. Therefore, the maximum loss of head can only be about 4 inches.

Since, under free-flow conditions, submergence should not exceed 70 percent, it will be necessary to determine loss of head for flumes of different sizes. Since, for economic purposes the flume should be the smallest size that can be used, the loss of head should be determined for the 1-, 2- and 3-foot flumes. To determine the respective loss of head refer to figure 5 in the appendix and proceed as follows: Find the point where the flow of 12 c.f.s. intersects the vertical line indicating a percentage of submergence of 70. From this point follow across the figure horizontally until the diagonal lines representing throat widths of 1, 2 and 3 feet are intersected, then drop down vertically to the bottom line which will indicate the loss of head in feet. We thus find the loss of heads for the 1-, 2- and 3-foot flumes to be 0.76, 0.49, and 0.37 foot, respectively. Therefore, the 3-foot flume is the smallest that should be used under free-flow conditions.

SUBMERGED FLOW

As previously stated, when the difference in elevation between the water surface at the Ha gage in the converging section and the water surface near the lower end of the throat section is less than 40 percent of the depth of water at the Ha gage for the 3-, 6- and 9-inch flumes, and less than 30 percent of Ha for the 1-foot and larger flumes, the flow ceases to be what is termed "free flow" and becomes a submerged flow. When the flow is submerged, and in order to obtain the degree of submergence, another gage must be installed near the lower end of the throat section. This gage is called the "Hb gage" and its location is shown in Plate F. Due to the water waves at the location for the Hb gage, it is necessary to place the gage in a stilling well. The location of the small pipe leading from the flume to the stilling well is shown on Plate F by the X and Y distances. The values for X and Y are given in the table on page 23. Unless it is necessary to install recorders no stilling well would be needed for the Ha gage.

The submergence of a flume is determined by dividing the Hb reading by the Ha reading. When the ratio of the two heads, Hb and Ha, exceeds 0.7 for flumes of throat widths of 1 foot or greater, the flow is submerged and it becomes necessary to apply a negative correction to the free-flow discharge in order to obtain the correct flow.

When this ratio exceeds 0.6 for the 3-, 6- and 9-inch flows, the submerged flow can be taken directly from figures 1, 2, and 3, following Table 7 in the appendix. The computed submerged flow for flumes having throat widths of 1 foot and greater is determined by use of Figure 4, appendix. This figure applies to a 1-foot flume but is made applicable to the larger flumes by multiplying the correction for the 1-foot flume by the factors given below; the product obtained is then subtracted from the free-flow discharge for the Ha head. The factors to be multiplied are:

Size of flume in feet	Multiplying factor	Size of flume in feet	Multiplying factor
1	1	5	3.7
1.5	1.4	6	4.3
2	1.8	7	4.9
3	2.4	8	5.4
4	3.1		

To illustrate this procedure, the following examples are given:

Example 1—What will be the discharge through a 9-inch flume with an Ha head of 0.64 foot and Hb of 0.55 foot?

Example 2—What will be the discharge through a 1-foot flume with Ha of 0.70 and Hb of 0.58?

Example 3—What will be the discharge through a 3-foot flume with Ha of 1.8 and Hb of 1.6?

Solutions—

In Example 1 the submergence is Hb/Ha = 0.55 ÷ 64 = 0.86 or 86 percent. Since this exceeds 0.6 submergence, the flow is submerged. Turning to Figure 3, appendix, we enter the figure at the left at submergence 86 percent and follow horizontally until the Ha curve is reached. Thence, follow vertically downward to the base of the diagram and obtain the actual discharge. In this case the discharge is 1.3 c.f.s.

In Example 2 the submergence is 0.58 ÷ 0.70 = 0.83 or 83 percent. Turning to Figure 4, appendix, enter the figure at left at the value for Ha of 0.70 and follow horizontally until the percentage of submergence curve is intersected and then follow vertically downward and obtain the correction at the base of the diagram. In this example the correction is found to be 0.28 c.f.s. This correction is a negative correction and since the multiplying factor is 1.0, it is subtracted from the free-flow discharge for Ha of 0.70 to obtain the actual discharge. From Table 7 for Ha of 0.70, free-flow discharge is 2.33 c.f.s. The solution is then 2.33 — 0.28 = 2.05 c.f.s. The loss of head from Figure 5 would be about 0.14 foot.

Example 3. Here the submergence is 1.6 ÷ 1.8 = 0.89 or 89 percent. Using Figure 4 as in Example 2 we find a correction for the 1-foot flume of about 2.45 c.f.s. Since in this example a 3-foot flume is used, the correction must be multiplied by the factor of 2.4 (above). The correction to be used is then 2.4 × 2.45 = 5.88. This figure subtracted from the free-flow discharge of 30.1 gives the corrected discharge of 24.22 c.f.s. The loss of head from Figure 5 would be about 0.22 foot.

GENERAL COMMENTS

Previously in this bulletin the operation of weirs was explained. It might be noted here that the weir, when operating under standard conditions of setting, is the most accurate of the common measuring devices. One disadvantage of the weir is that its successful operation requires a relatively large loss of head. As the Parshall flume under free flow requires only about one-fourth the loss of head required for a weir, the flume can be used where it is impossible to successfully use a weir.

The accuracy of the Parshall measuring flume is within the limits permissible in irrigation practice. Careful measurements by means of a current meter and submerged orifice indicated that the flumes were measuring within an accuracy of 2 percent, although ordinarily the range of accuracy is within 5 percent.

It has previously been stated that when the velocity of the water approaching a weir is greater than 0.5 feet per second, the actual discharge becomes greater than that indicated by the gage reading and corrections have to be made. This difference is not great for moderate velocities, say from 0.5 to 1.0 foot per second, but increases rapidly as the velocity increases. As the procedure for making the added correction requires a mathematical computation, it is often the case that the correction is made by guess, if at all, and therefore the weir ceases to be a proper measuring device.

The velocity of approach in the case of the Parshall flume does not materially affect the rate of discharge. Experiments have shown that on a 2-foot flume an increase of 85 percent in the velocity of approach showed no effect on the indicated rate of discharge.

As the velocity through the flume is higher than that in the channel, silt will not deposit in the structure where it would affect the accuracy. In other words, the flume is self-cleaning. As there are no moving parts in the Parshall flume the operation is simple, and its dimensions are not easily changed so as to cause willfully unfair measurements.

The range of capacity of discharge is from 0.10 c.f.s. through a 3-inch flume to over 1,500 c.f.s. through a 40-foot flume.

The Parshall flume has certain disadvantages, as all measuring devices have. The main disadvantage is that the flume cannot be used or combined with a turnout or headgate. The flume is also more expensive to build or purchase than the ordinary weir or submerged orifice headgate construction, and requires more accurate workmanship in construction.

In conclusion, it might be well to state that after the Parshall flume has been installed, care should be exercised to keep it in good condition. The flume, properly installed, will have a long life, but it is quite easy, especially in small sizes, to cause damage by unnecessary tramping on and around the structure. If the flume has a tendency to act as a bridge across the channel, it is a good plan to place a walk over the structure so that the pressure caused by a person stepping on or near the throat section will not tend to push the sides out of place.

STREAM GAGING

The two generally accepted methods for determining the quantity of water flowing in an open stream or channel are the weir method and the velocity-area method. The weir method previously discussed is used mainly on small flows and will not be discussed further, due to the fact that the use of weirs on larger streams is expensive. The velocity-area method is extensively used, not only due to the comparative inexpensiveness, but to the fact that it is a reliable method of determining flow under a wide range of conditions.

In using the velocity-area method of determining flow of water the velocity of the water at certain designated points must be obtained. The mean velocity over a certain cross-sectional area multiplied by the area of the cross-section gives discharges in cubic feet per second. The cross-sectional area of the channel is determined by measuring the depths of water at the most suitable points to show the shape of the channel. The distance between the points multiplied by the average depth of the water at these points gives the partial area, and the total area of the cross-section is the summation of these partial areas. The velocity may be measured by:

1. Float.
2. Current meter.
3. Slope method.

1. The determination of velocity of water by the float method has previously been discussed and will not be enlarged upon here, except to state that where proper precautions are used this method gives fair results. The errors most often made in using this method lie mainly in using whatever object close at hand for a float and not applying the proper coefficient to obtain the mean velocity. The coefficient varies between 0.70 and 0.90 and the average would be about 0.80, which is the suggested coefficient to use. Another way in which errors may occur is in not obtaining proper distributed observation of velocity. In other words, several observations should be made with the float in different positions as the velocities are higher near the middle of the stream.

2. Of the various methods used to determine velocities of flowing water in an open channel, stream or river, the current meter method is the most convenient and the most commonly used. This method may not be practical for the layman because he may not have access to a current meter, and the cost of purchasing one may not be justified. However, for the engineer it is practical because of reasonable cost, accuracy, and applicability, and can be used on any open body of flowing water, whether it is a farm ditch or a river.

The current meter usually operates on the principle of a bucket wheel, rotating horizontally on a vertical axis. When the wheel is immersed in flowing water the velocity of the water causes the wheel to rotate. The observer notes the number of revolutions in a certain number of seconds and from a velocity table prepared for that particular meter determines the velocity in feet per second.

The two types of meters used are the electric meter and the acoustic

PLATE G

ALFRED MERRITT SMITH
STATE ENGINEER
CARSON CITY, NEVADA

CURRENT METER NOTES

DATE August 31, 1939. 10 A.M. STREAM Pepper ? C.

PARTY Shamberger & Donders LOCALITY At Millar's Diversion

METER NO. 616 GAGE HEIGHT, BEG. 1.1 ; END 1.1 ; MEAN 1.1

TOTAL AREA ______ MEAN VELOCITY ______ DISCHARGE ______

OBSERVATIONS					COMPUTATIONS						
					VELOCITY						
Distant from initial point	Depth	Depth observation	Time in seconds	Revolutions	At point	Mean in vertical	Mean in section	Mean depth	Width	Area	Discharge
0											
							.043	0.3	0.5	.015	0.06
0.5	0.6	0.4	60	20	0.86	0.86					
							0.89	0.9	2.0	1.8	1.60
2.5	1.2	0.7	54	20	0.92	0.92					
							0.94	1.5	2.0	3.0	2.82
4.5	1.8	0.4	50	20	0.98	0.96					
		1.4	52	20	0.94		1.00	1.9	2.0	3.8	3.80
6.5	2.0	0.4	45	20	1.05	1.03					
		1.6	47	20	1.01		1.04	1.9	2.0	3.8	3.95
8.5	1.8	0.4	44	20	1.07	1.05					
		1.4	47	20	1.02		1.00	1.35	2.0	2.7	2.70
10.5	0.9	0.5	52	20	0.95	0.95					
							0.90	0.75	1.0	0.75	0.68
11.5	0.6	0.4	67	20	0.84	0.84					
							0.42	0.3	0.5	.015	0.06
12.0	0										
					Total Discharge						15.67

NO. 1 OF 1 SHEETS. COMP. BY H.A.S. CHK. BY F.N.D.

MAKE NOTES ON BACK

NOTE—Plate G has been prepared to illustrate the method of recording the observations and computing the data. On such a section observations should be taken every foot, but space prevented showing the approved number of sections.

meter. In the former method an electric clicker operated by a small dry-cell battery indicates the revolutions which are transmitted to the observer by means of an earphone, and in the latter method the revolutions of the wheel are indicated by a hammer striking against the diaphram in an enclosed chamber. The sound is transmitted to the ear of the observer by means of a hollow wading rod and connected rubber tubing with earphone. This method can only be successfully used when the operations are carried on in a shallow stream.

The most improved meters are so constructed that each revolution of the bucket wheel may be indicated for use in low water velocities, and where the velocities are higher it can be adjusted so that every fifth revolution is indicated. Some meters are so constructed that every tenth revolution is indicated. In making a measurement the observer should use a stop watch to determine the number of revolutions in a certain number of seconds. By means of the table accompanying the meter the corresponding velocity may be noted.

Current meters are rated by drawing them through still water at known or observed velocities and counting the revolutions. By making a number of tests at different velocities a curve can be made up. However, the best way to have a current meter rated is to send it in to the U. S. Bureau of Standards, Washington, D. C. When meters are purchased, for a small extra charge, the manufacturer will deliver it through the Bureau of Standards with a true rating table.

In taking a measurement the observer may stand on a bridge that crosses the stream with a clear span. If no bridge is available and the stream not wide, a temporary platform may be used, or if water is shallow the observer may wade. The latter method is not recommended when accurate results are desired, due to the fact that the observer's body will offer some obstruction which will affect the registration of the meter.

A satisfactory method is as follows:

A cross-section is selected where the water flows smoothly and the velocity is reasonably uniform across the section and should be near the lower end of a straight section of the stream. A range is laid off at right angles to the direction of flow, and is divided off into any desired number of parts. Sufficient observation of depth and velocity must be made to disclose the true area of the cross-section and true velocity. On streams up to forty feet wide observations are made at points one to two feet apart. For larger streams observations can be made five or ten feet apart. This rests with the observer as to the number of observations to take to get true velocity averages and areas. However, it must always be remembered that the more observations, the closer the result will be.

The range may be marked in any way that is convenient. For small streams a satisfactory way is to stretch a tape across the stream and arrange it so that the zero of the tape is at the edge of the water. Soundings are then taken at each point of division decided on to determine the depth of the water. From this data the area of each subdivision can be determined. Oftentimes where a plank or bridge is used the points of division can be marked on the edge.

Having determined the depth of the water at each division point and the distance apart, the mean velocity is determined at each point by means of the current meter. Observations have determined the fact that velocities of water decrease as the bottom of the stream bed is approached. It has been proven that the velocity at 0.6 depth or the average of the velocities at 0.2 depth and 0.8 depth are very nearly the average of all velocities in the vertical section. For this reason it is possible to get a fairly accurate uniform velocity of any one section by one observation at 0.6 depth, or more accurately by taking the average of velocity at 0.2 depth and 0.8 depth.

It is always advisable to compute the discharge before leaving the place of observation, for the reason that if any inaccuracies are discovered, the observations can be retaken.

The observer should see that his instrument is wiped dry and oiled before returning same to its box.

Figure 4, Plate C, shows the manner in which a stream is divided off, and Plate G shows the corresponding current meter notes.

The current meter when properly used will measure velocities within a probable error of 2 percent. The principal sources of error in current meter measurements of discharge are in the determination of depths of water; in placing the meter at proper depths to get the average velocity; in observations of time, in the use of insufficient number of observations to obtain velocities and areas, and in the maintainence of the meter after it has been rated.

In shallow streams where the observer is close to the water surface or else wading in the water, the meter is attached to a wading rod on which feet and tenths of feet are designated. In deeper streams or where the observer is on a bridge and some distance above the water surface the meter is used in conjunction with a cable.

A lead weight is attached underneath the meter to assist in keeping it in position. In measuring depths the observer may mark a point on the cable in reference to edge of bridge where the weight is just touching the water and again mark a point where the weight is resting on the bottom. The distance between these points on the cable is the depth of water at that point.

It must be remembered that the current meter is an instrument of precision and too much emphasis cannot be placed on the careful transporting, handling, and general care of it.

3. The determination of velocity by the slope method is obtained by use of a formula, of which there are several. The Manning formula is recommended by many leading authorities and for open channels is given as

$$V = \frac{1.486}{n} r^{2/3} S^{1/2}$$

where r = hydraulic radius = area of cross-section of stream in square feet divided by the wetted perimeter in feet.

S = slope = fall of channel divided by length over a certain section.

n = coefficient of roughness.

The value of the coefficient of roughness "n" for unlined canals and ditches will vary from 0.017 to 0.020 for those in good condition and from 0.02 to 0.035 for those in poor condition. The quantity of water that will flow in an open channel is dependent upon several conditions which are the slope, the area, the condition of the sides and bottom, and the shape of the channel.

This method is usually used to determine the size of ditch to construct to carry a certain amount of water and is also used in the determination of flows during flood stages after the peak is past and when the data available is the high water mark along the sides of the channel from which the cross-sectional area and slope may be determined.

Due to the complexity of the formula and difficulty in determining the proper coefficient "n" the use of this method is usually restricted to engineers, and so will not be further discussed here.

GAGING STATIONS

The successful operation of a gaging station is based on the assumption that the discharge at any given stage will be unchanged so long as the bed and banks of the stream at the gage station remain unchanged, and that the discharge will vary with the stage according to a fixed relation. The relation between discharge and stage makes it possible to construct a rating curve from current meter observation at different stages of the flow. In other words, to construct a rating curve for a specific section of a river the observer must make several observations for discharge with the flow at different stages. The elevation of the surface of the water is determined by means of a gage permanently set. The discharge in relation to gage heights are platted and a curve is drawn as nearly as possible through the average of these points. Such a curve is parabolic in form. Following the construction of the rating curve the flow of water for any immediate stage can be determined by merely noting the gage height, and from the rating curve obtain the discharge for that gage height.

Where no changes take place in the stream channel, measurements made in different years will plat along the same curve. However, in many instances it is necessary to construct a rating curve every season and sometimes more than one during a season.

The relation between the gage height and discharge will be stable when there exists below the gage an effective control section in which the bed and banks are permanent. Such a control may be found in a long stretch of the river having a low gradient; at an artificial structure in the channel, and at the head of rapids where the fall is steep.

It is obvious that a section should not be chosen that lies just above a dam or structure where the flow can be controlled by opening and closing gates.

A station should be selected when possible so as to give as large a change in gage readings as is possible for a given change in discharge.

In selecting a gaging station care should be given to obtaining a location where the bed and banks of the stream are as permanent as possible and where the current is smooth and the velocity is measurable, that is, between 0.5 and 15 feet per second.

In the selection of a station, the accessibility of the site should not be given too much consideration. The cost over a number of years between a stable station somewhat inaccessible and an unstable station easy to get to rests in favor of the former. Recording gages are now obtainable that will record gage height accurately for sixty days or more without attention.

Following the selection of a site, the establishment of a station consists in the installation of a gage and a cable, or a supporting platform from which the measurements may be made.

The gage should be located where it can be easily read and be in such a position that it will be undisturbed. In setting the gage the zero of the gage should be referred to a permanent bench mark so in case the gage is disturbed it can be reset. The most common gage is the staff gage, which may be set either vertically or inclined. When set on an incline a level should be used to mark the feet and tenths of feet after the gage is in place. Such a gage may be painted directly on wood or metal. The gage should be set on rock or concrete so that the datum will remain constant. When attached to a tree at the water's edge or a wooden piling, the datum must be frequently watched and accuracy checked.

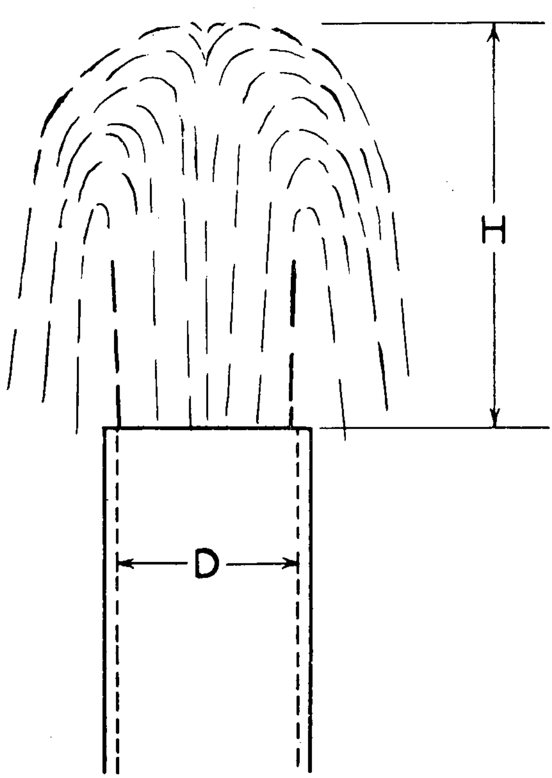
Where daily discharges are necessary, an automatic water level recorder is installed. The installation consists of a platform rigidly set to support the recorder; a float-well at least 36 inches in diameter, so connected with the flowing water in the river that the stage of water will be the same; a shelter or gage house to protect the recorder against the elements and also against malicious molestations. When the float-well is located away from the river bank it is connected to the river by means of an intake pipe which should always be kept open. Where possible, the well may be directly connected with the river and the intake pipe omitted.

Where an automatic recording station is installed, there should always be a nonrecording gage, as previously described. The nonrecording gage should be read and recorded whenever the station is visited in order that a check may be made of the automatic recorder.

MEASURING DISCHARGE FROM PIPES

Frequently the discharge from an artesian well or from a pumping plant is desired when there are no facilities for making a measurement by methods in common use. For such measurements coordinate methods[1] of measuring pipe flow have been suggested. However, these methods have limited accuracy and should not be used where accuracy is essential or where some other method can be conveniently used.

These methods consist of measuring the coordinates of a point in the jet issuing from the end of the pipe; the chief difficulty is in accurately measuring the coordinates. The flow from pipes may be measured whether the pipe is discharging vertically upward, horizontally, or at some angle with the horizontal. Usually discharge pipes from artesian wells or pumping plants are



Drawing showing dimensions necessary in making a measurement of the flow from vertical pipes.

[1]Christiansen, J. E., "Coordinate Methods of Measuring Pipe Flow." Mimeographed report of Division of Irrigation Investigations and Practice, University of California.

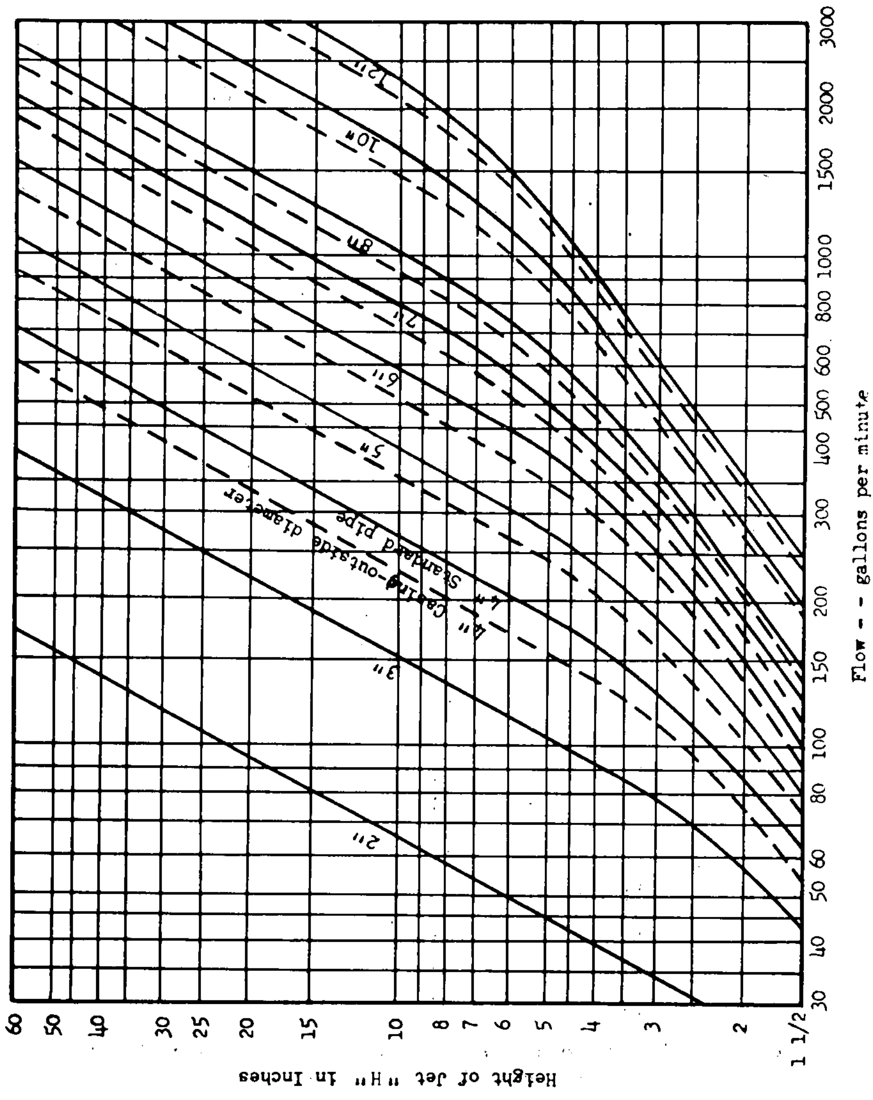


Plate H Discharge curves for measurement of flow from vertical pipes. Based on data from experiments of Lawrence and Braunworth. Am. Soc., C. E. Trans. (57) 1906.c either vertical or horizontal and therefore only these two cases will be discussed here.

Vertical Pipes. Lawrence and Braunworth[2] conducted an extensive set of experiments to determine the flow from vertical pipes. They found that when the height of the jet exceeds 1.4 D, as determined by sighting over the jet to obtain the maximum rise, the flow can be expressed by the empirical equation:

$$G.P.M. = 5.01\, D^{1.99}\, H^{0.53}$$

When the height of the jet is less than 0.37 D, the flow is similar to that over a weir and can be expressed by the equation:

$$G.P.M. = 6.17\, D^{1.25}\, H^{1.35}$$

in which G.P.M. is flow in gallons per minute; D is the diameter of the pipe in inches; and H is the height of the jet in inches.

For jet heights between 0.37 D and 1.4 D the flow is somewhat less than that given by either of these equations.

Figure 33 shows the flow in gallons per minute for pipe and casing 2 to 12 inches in diameter, for jet heights, H, from 1½ to 60 inches. This diagram was prepared from Lawrence and Braunworth's data, using the actual inside diameter of standard pipe and casing as given in pipe handbooks.

Horizontal Pipes. For pipes discharging horizontally, it is necessary to measure both a horizontal and a vertical distance from some point on the end of the pipe to a similar point in the jet. These horizontal and vertical distances are called the X and Y ordinates, respectively. In the method described by Slichter, the ordinates are measured from the center of the end of the pipe to the center of the jet, as shown in Figure 34. The expression for the flow from completely filled pipes is derived in the following manner: The distance Y that a particle falls in time, t, after issuing from the end of a horizontal pipe is

$$Y = \frac{g\, t^2}{2}$$

and the horizontal distance X it travels is

$$X = V\, t \quad \text{where V is the}$$

initial horizontal velocity. Combining these equations by eliminating t and solving for V, we obtain:

$$V = \frac{X\sqrt{g}}{\sqrt{2\,Y}}$$

from which we obtain the expression for the flow in cubic feet per second, all dimensions being in feet:

---

[2]Lawrence, F. E., and P. L. Braunworth. "Fountain Flow of Water in Vertical Pipes." American Society of Civil Engineers, Trans. No. 57, p. 265–306. 1906.

$$Q = \frac{C\ A\ X \sqrt{g}}{\sqrt{2\ Y}}$$

It is interesting to note that this expression also holds for pipes discharging at an angle with the horizontal when the *X ordinate is measured parallel with the axis of the pipe and the Y ordinate is measured vertically.*

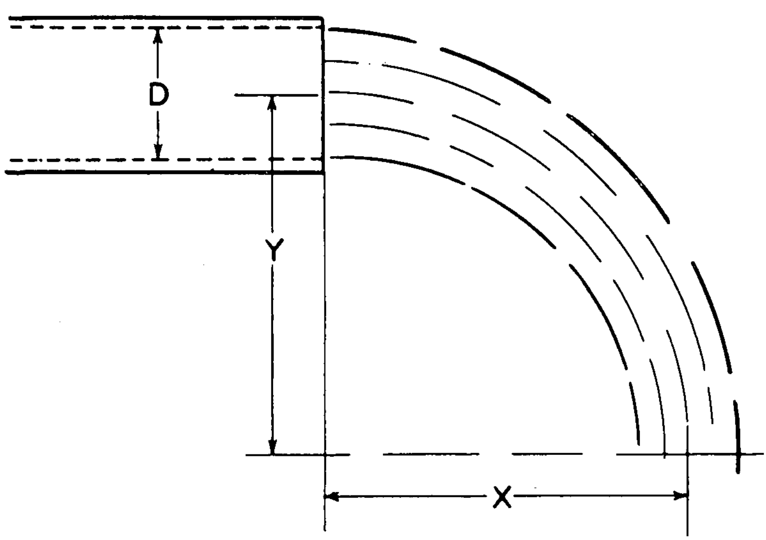
For flow in gallons per minute, with the ordinates and pipe diameter in inches, the expression is:

$$G = \frac{2.84\ C\ D^2\ X}{\sqrt{Y}}$$

For any given pipe diameter and given value of Y, the flow is directly proportional to the Y ordinate.

The flow from pipes ranging from 2 to 8 inches in diameter and values of Y of 12 and 24 inches, respectively, is given in Figure 35. Since experimental data are lacking, a value of C = 1.0 was used in computations for these diagrams.

The flow from partially filled horizontal pipes can be estimated by multiplying the flow obtained from the diagram by the percentage of the area of the pipe that is filled at the end of the pipe. The coordinates should be measured from the approximate center of the jet at the end of the pipe instead of from the center of the end of the pipe. The Purdue method described below is generally more accurate, especially for partially filled pipes.



Drawing showing dimensions necessary in making a measurement of the flow from horizontal pipes.

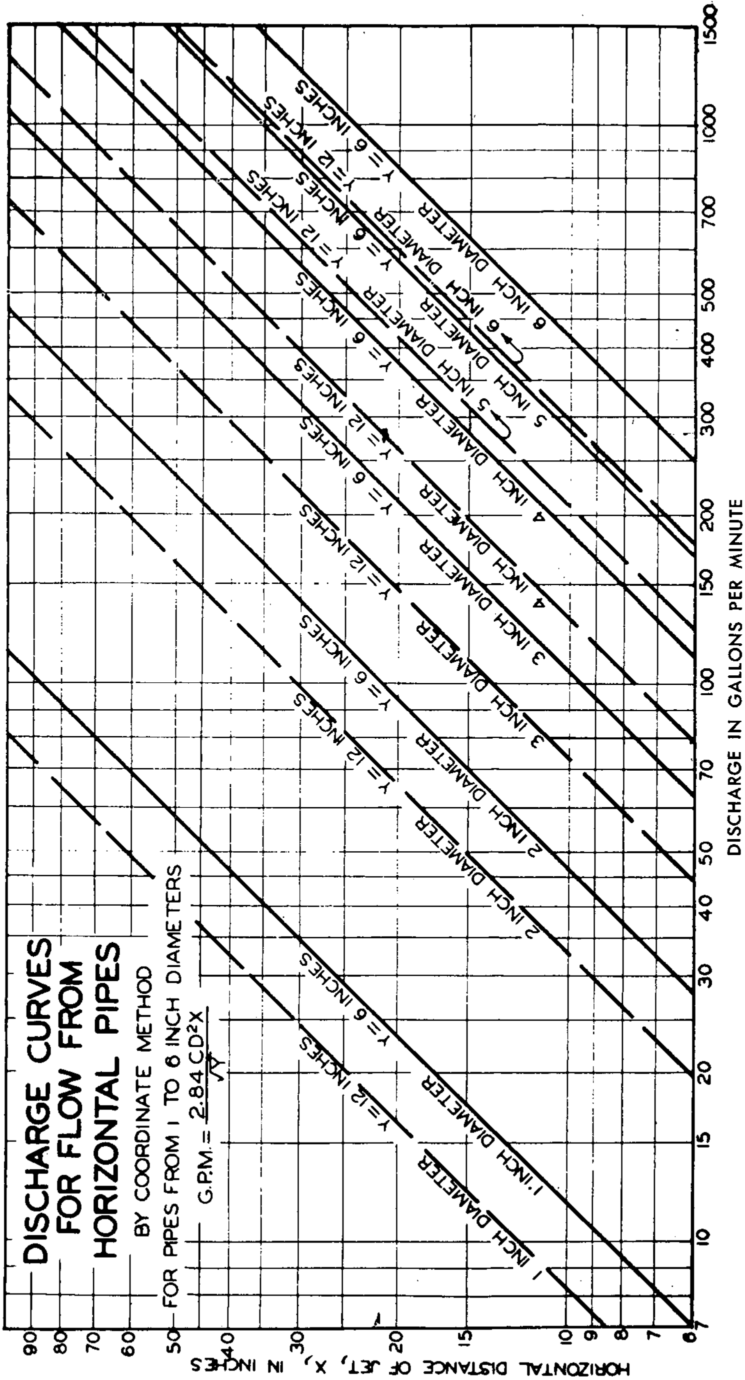
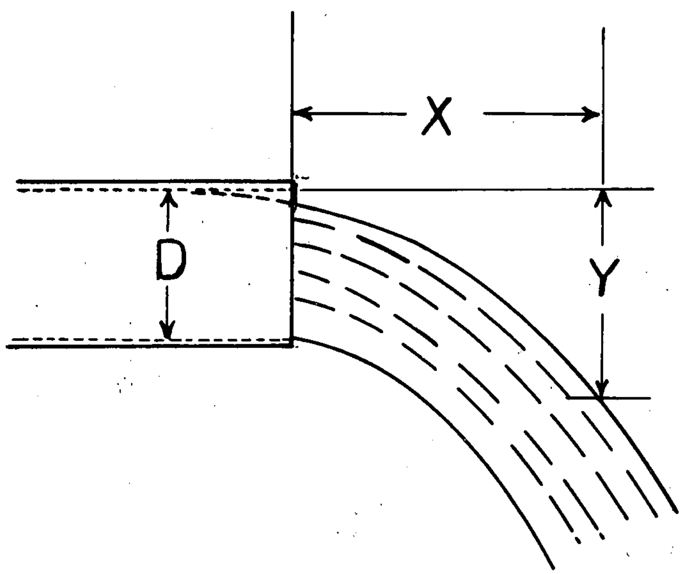


Plate I Discharge curves for flow from horizontal pipes.

Purdue Method for Horizontal Pipes. Another coordinate method of measuring pipe flow has been developed at Purdue University.[3] It consists of measuring the coordinates of the upper surface of the jet as shown in Figure 36. For pipes flowing less than 0.8 full at the end, the vertical distance Y can be measured at the end of the pipe where X = O. The flow from pipes ranging from 2 to 6 inches in diameter is given in Figure 37. These diagrams were prepared from data taken from Purdue Engineering Experiment Station Bulletin No. 32, and are based on tests on standard pipe sizes only. The curves for the casing have been drawn in by interpolation.

For accurate results, the pipe must be level and of sufficient length so that the water is flowing fairly smoothly when it issues from the pipe. If the pipe slopes upward, the measurements will be too high and if it slopes downward, they will be too low. The top of the jet is not sharply defined and it is difficult to make an exact measurement of the distance Y.



Purdue method of measuring pipe flow.

[3]Greve, F. W. Measurement of pipe flow by the coordinate method. Purdue Engineering Exp. Sta. Bul. 32. 1928.

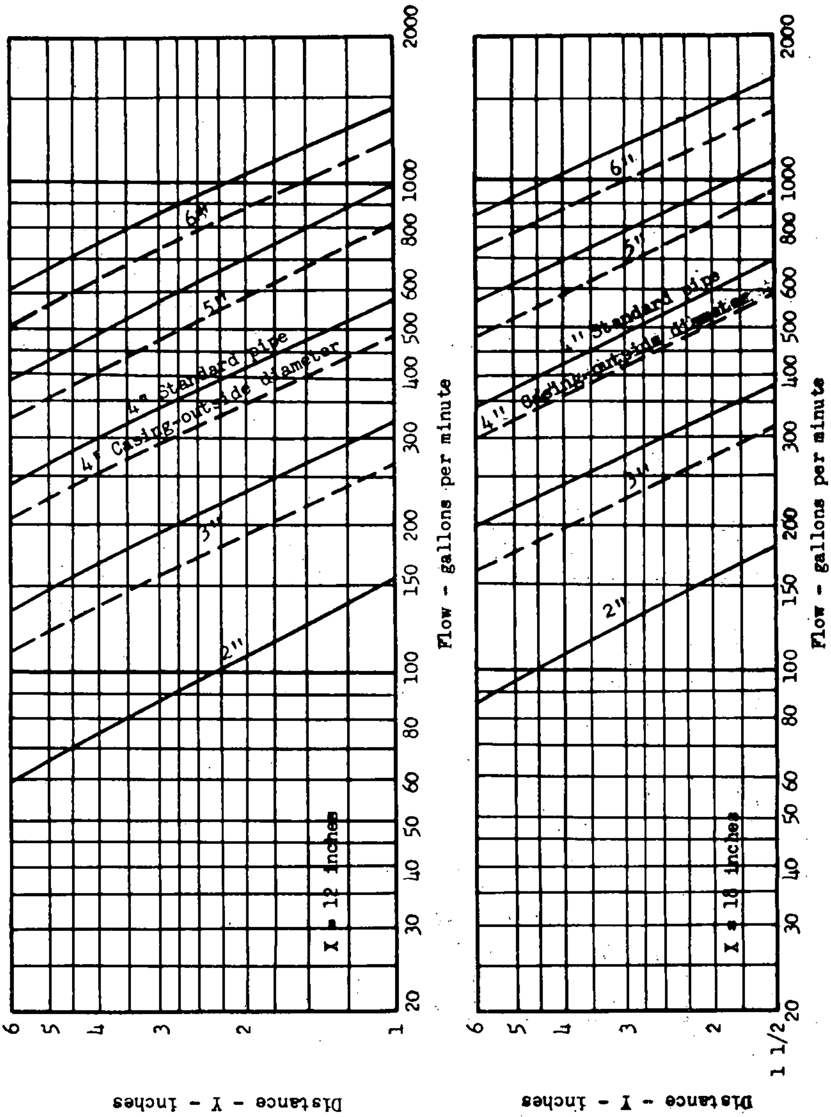


Plate J Flow from horizontal pipes by Purdue coordinate method.

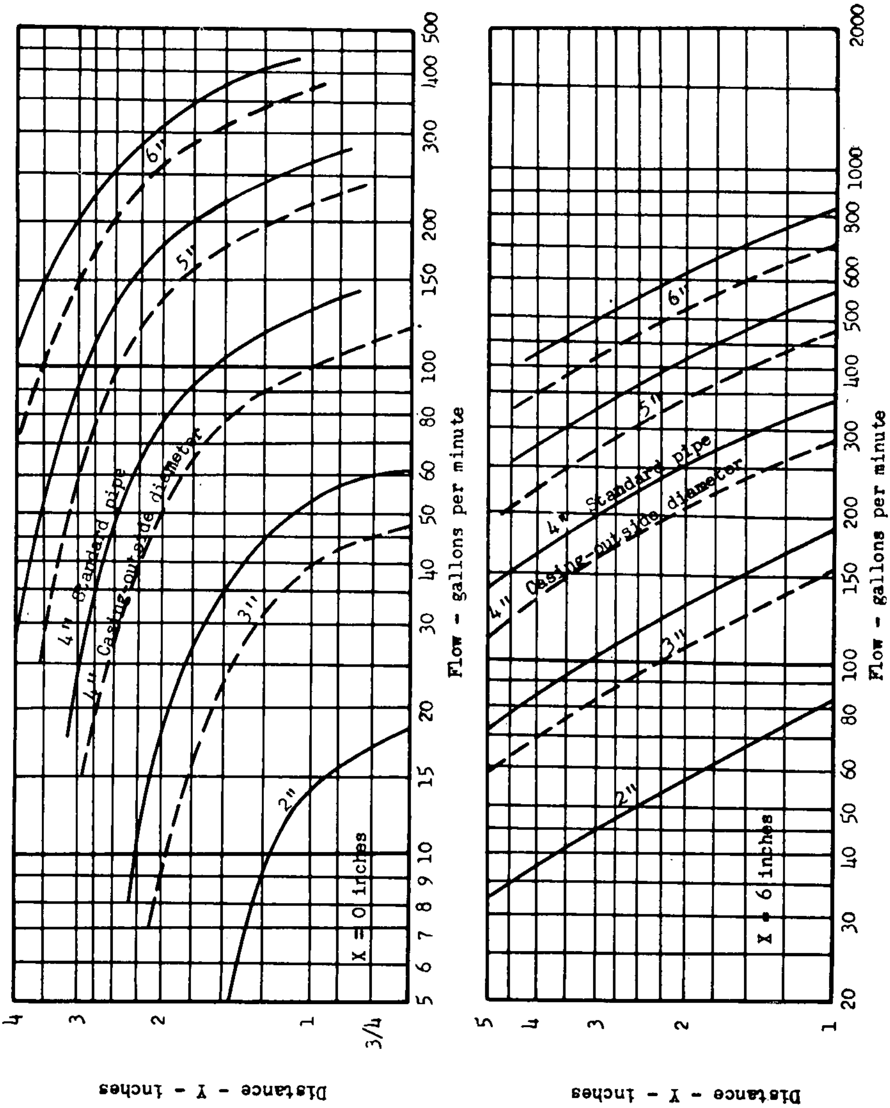


Plate J Flow from horizontal pipes by Purdue coordinate method.

WATER AND WATER POWER EQUIVALENTS

WATER

One acre foot of water is the quantity that will cover an area of one acre one foot deep—
= one cubic foot per second of water flowing continuously for 12 hours and six minutes.
= 43,560 cubic feet.
= 325,851 gallons.

One second-foot of water is the quantity that will fill a space of one cubic foot in one second of time—
= 40 miner's inches in Nevada.
= 7.4805 gallons per second.
= 448.83 gallons per minute.
= 1.983 acre feet per day.
= 646,315.2 gallons per day.

One miner's inch of water in Nevada is the approximate flow through an orifice with an area of one square inch under a head of 6¼ inches—
= 0.025 (1/40) cubic foot or 0.186 + gallons per second.
= 11.22 gallons per minute.
= 673.20 gallons per hour.
= 1 acre inch in 40 hours and 20 minutes.
= 1 acre foot in 484 hours (approximately 20 days), or 0.0496 acre foot (approximately 1/20) per day.
= 16,156.80 gallons in 24 hours.

Million gallons per day—
= 1.547 cubic feet per second (c.f.s.).
= 694.4 gallons per minute.
= 61.89 miner's inches.
= 1 acre foot in 7 hours and 49 minutes, or 3.07 acre feet per day.

One gallon per minute—
= 0.00223 (1/449) cubic foot per second.
= 0.0891 (approximately 1/11) statutory miner's inch.
= 1 acre foot in 226.3 days or 0.00442 acre foot per day.

One miner's inch flowing 150 days (5 months of 30 days each) will cover an acre of land 7.4 feet deep.

One second-foot of water flowing 150 days equals 297.45 acre feet, or enough water to cover 100 acres of land 2.9745 feet deep.

One cubic foot—
= 1,728 cubic inches.
= 7.48 gallons of water, weighing approximately 62.5 pounds.

One gallon—
= 231 cubic inches.
= 0.13368 cubic foot, weighing approximately 8.34 pounds.

To find water pressure in pounds pressure per square inch, multiply height of head or column of water measured in feet by 0.434.

Pounds pressure per square inch multiplied by 2.31 gives head of water in feet.

To convert gallons per minute to cubic feet per second or vice versa refer to the last two columns in Table 3.

CONVERSION TABLE FOR UNITS OR FLOW*

Cubic feet per second	Gallons per minute	Million gallons per day	Nevada Statute miner's inches	Acre inches per 24 hours	Acre feet per 24 hours
1.0	448.83	0.646	40.0	23.80	1.983
0.00223	1.0	0.00144	0.0891	0.053	0.00442
1.547	694.44	1.0	61.89	36.84	3.07
0.025	11.22	0.0162	1.0	0.595	0.0496
0.042	18.86	0.0271	1.68	1.0	0.0833
0.504	226.28	0.3258	20.16	12.0	1.0

*Equivalent values are given in the same horizontal line.

The approximate depth of water applied to a field may be compiled from the following formulas:

$$\frac{\text{Cu. ft. per sec.} \times \text{hours}}{\text{acres}} = \text{Acre inches per acre, or average depth in inches.}$$

$$\frac{\text{Gals. per min.} \times \text{hours}}{450 \times \text{acres}} = \text{Acre inches per acre, or average depth in inches.}$$

$$\frac{\text{Miner's inches} \times \text{hours}}{40 \times \text{acres}} = \text{Acre inches per acre, or average depth in inches, where one miner's inch} = 1/40 \text{ c.f.s.}$$

Area of Circle $= 3.1416\ r^2 = 0.7854\ d^2$
Circumference of Circle $= 3.1416\ d$
Where r = radius of circle and d = diameter of circle.

WATER TABLES FOR MINING, MILLING, METALLURGICAL OPERATIONS

1 miner's inch of water......... = 673.20 gallons per hour.
= 5,614.5 pounds of water per hour.
= 2.81 tons of water per hour.
= 134,748 pounds of water per 24 hours.
= 67.37 tons of water per 24 hours.

1 gallon per minute............... = 8.34 pounds of water per minute.
= 500.4 pounds of water per hour.
= 0.25 tons of water per hour.
= 12,010 pounds of water per 24 hours.
= 6 tons of water per 24 hours.

1 second-foot of water........... = 7.48 gallons per second.
= 62.4 pounds of water per second.
= 448.83 gallons per minute.
= 3,743.2 pounds of water per minute.
= 1.87 tons of water per minute.
= 26,930 gallons per hour.
= 224,596 pounds of water per hour.
= 112.3 tons of water per hour.
= 646,315 gallons per 24 hours.
= 5,390,267 pounds of water per 24 hours.
= 2,695 tons of water per 24 hours.

To convert tons of water to—
Miner's inches, continuous flow for 24 hours, divide by 67.37.
Gallons per minute, continuous flow for 24 hours, divide by 6.
Cubic feet per second, continuous flow for 24 hours, divide by 2.695.

POWER

1 cubic foot of water = 62.5 pounds.
1 horsepower = 550 foot-pounds per second.
1 horsepower = 33,000 foot-pounds per minute.
1 horsepower = 746 watts or .746 kilowatts (kw.).
1 horsepower = 1 second-foot of water falling 8.8 feet (100% efficiency).

Horsepower developed at water wheel at 80% efficiency =

$$\frac{\text{Second-feet} \times \text{fall in feet}}{11}$$

The horsepower required to lift any quantity of water any specified distance may be obtained from the following formula:

$$\text{Horsepower} = \frac{\text{g.p.m.} \times \text{h}}{4{,}000 \times \text{E}} \text{ (approximately).}$$

when g.p.m. = gallons pumped per minute.

h = total head in feet against which pump must work. This includes total material lift, plus frictional and other losses.

E = Efficiency of pump (expressed as a decimal fraction).

Theoretical horsepower developed by potential water source =

$$\frac{10 \times \text{h} \times \text{c.f.s.}}{88}$$

when h = head in feet; c.f.s. = second feet of water discharge.
1 kilowatt = 1.341 horsepower.
1 kilowatt = 1,000 watts.
1 kilowatt = 737 foot-pounds per second.

A kilowatt-hour is the quantity of energy resulting from the utilization of 1 kilowatt of power for one hour of time.

Electrical energy yearly in kilowatt-hours
= horsepower × 0.746 × 24 × 365 = horsepower × 6,534.96.

To reduce kilowatt-hours (kw.-hrs.) per year to continuous kilowatts divide by 8,760 (365 days × 24 hrs.).

To reduce kilowatt-hours per year to continuous horsepower, divide by 6,534.96 (0.746 × 24 × 365).

Power is defined as the time rate of doing work. A kilowatt and a horsepower are both units of power. Power multiplied by time gives energy or work.

Thus 1 kw. of power acting for 1 hour of time yields the unit of energy called 1 kw.-hour. Likewise 1 hp. of power acting for 1 hour of time yields 1 hp.-hour of energy.

Power should not be confounded with energy.

APPENDIX

TABLE 1

Flow Over Rectangular Contracted Weirs in Cubic Feet per Second*

Head in feet "H"	Head in inches, approx.	Crest Length (L) (Flow in cubic feet per second) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
0.10	1 3/16	0.105	0.158	0.212	0.319	0.427	0.108
0.11	1 5/16	0.121	0.182	0.244	0.367	0.491	0.124
0.12	1 7/16	0.137	0.207	0.277	0.418	0.559	0.141
0.13	1 9/16	0.155	0.233	0.312	0.470	0.629	0.159
0.14	1 11/16	0.172	0.260	0.348	0.524	0.701	0.177
0.15	1 13/16	0.191	0.288	0.385	0.581	0.776	0.196
0.16	1 15/16	0.210	0.316	0.423	0.638	0.854	0.216
0.17	2 1/16	0.229	0.346	0.463	0.698	0.934	0.236
0.18	2 3/16	0.249	0.376	0.504	0.760	1.02	0.257
0.19	2 1/4	0.270	0.407	0.546	0.823	1.10	0.278
0.20	2 3/8	0.291	0.439	0.588	0.887	1.19	0.303
0.21	2 1/2	0.312	0.472	0.632	0.954	1.28	0.326
0.22	2 5/8	0.335	0.505	0.677	1.02	1.37	0.35
0.23	2 3/4	0.358	0.539	0.723	1.09	1.46	0.37
0.24	2 7/8	0.380	0.574	0.769	1.16	1.55	0.39
0.25	3	0.404	0.609	0.817	1.23	1.65	0.42
0.26	3 1/8	0.428	0.646	0.865	1.31	1.75	0.44
0.27	3 1/4	0.452	0.682	0.914	1.38	1.85	0.47
0.28	3 3/8	0.477	0.720	0.965	1.46	1.95	0.49
0.29	3 1/2	0.502	0.758	1.02	1.53	2.05	0.52
0.30	3 5/8	0.527	0.796	1.07	1.61	2.16	0.55
0.31	3 3/4	0.553	0.836	1.12	1.69	2.26	0.57
0.32	3 13/16	0.580	0.876	1.18	1.77	2.37	0.60
0.33	3 15/16	0.606	0.916	1.23	1.86	2.48	0.62
0.34	4 1/16	0.634	0.957	1.28	1.94	2.60	0.66
0.35	4 3/16	0.661	0.999	1.34	2.02	2.71	0.69
0.36	4 5/16	0.688	1.04	1.40	2.11	2.82	0.71
0.37	4 7/16	0.717	1.08	1.45	2.20	2.94	0.74
0.38	4 9/16	0.745	1.13	1.51	2.28	3.06	0.78
0.39	4 11/16	0.774	1.17	1.57	2.37	3.18	0.81
0.40	4 13/16	0.804	1.21	1.63	2.46	3.30	0.84
0.41	4 15/16	0.833	1.26	1.69	2.55	3.42	0.87
0.42	5 1/16	0.863	1.30	1.75	2.65	3.54	0.89
0.43	5 3/16	0.893	1.35	1.81	2.74	3.67	0.93
0.44	5 1/4	0.924	1.40	1.88	2.83	3.80	0.97
0.45	5 3/8	0.955	1.44	1.94	2.93	3.93	1.00
0.46	5 1/2	0.986	1.49	2.00	3.03	4.05	1.02
0.47	5 5/8	1.02	1.54	2.07	3.12	4.18	1.06
0.48	5 3/4	1.05	1.59	2.13	3.22	4.32	1.10
0.49	5 7/8	1.08	1.64	2.20	3.32	4.45	1.13
0.50	6	1.11	1.68	2.26	3.42	4.58	1.16
0.51	6 1/8	1.15	1.73	2.33	3.52	4.72	1.20
0.52	6 1/4	1.18	1.78	2.40	3.62	4.86	1.24
0.53	6 3/8	1.21	1.84	2.46	3.73	4.99	1.26
0.54	6 1/2	1.25	1.89	2.53	3.83	5.13	1.30
0.55	6 5/8	1.28	1.94	2.60	3.94	5.27	1.33
0.56	6 3/4	1.31	1.99	2.67	4.04	5.42	1.38
0.57	6 13/16	1.35	2.04	2.74	4.15	5.56	1.41
0.58	6 15/16	1.38	2.09	2.81	4.26	5.70	1.44
0.59	7 1/16	1.42	2.15	2.88	4.36	5.85	1.49
0.60	7 3/16	1.45	2.20	2.96	4.47	6.00	1.53
0.61	7 5/16	1.49	2.25	3.03	4.59	6.14	1.55
0.62	7 7/16	1.52	2.31	3.10	4.69	6.29	1.60
0.63	7 9/16	1.56	2.36	3.17	4.81	6.44	1.63
0.64	7 11/16	1.60	2.42	3.25	4.92	6.59	1.67

*Computed from Cone's formula. For field computation use Francis's formula.

Table No. 1—*Continued*

Head in feet "H"	Head in inches, approx.	Crest Length (L) (Flow in cubic feet per second) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
0.65	7 13/16	1.63	2.47	3.32	5.03	6.75	1.72
0.66	7 15/16	1.67	2.53	3.40	5.15	6.90	1.75
0.67	8 1/16	1.71	2.59	3.47	5.26	7.05	1.79
0.68	8 3/16	1.74	2.64	3.56	5.38	7.21	1.83
0.69	8 1/4	1.78	2.70	3.63	5.49	7.36	1.87
0.70	8 3/8	1.82	2.76	3.71	5.61	7.52	1.91
0.71	8 1/2	1.86	2.81	3.78	5.73	7.68	1.95
0.72	8 5/8	1.90	2.87	3.86	5.85	7.84	1.99
0.73	8 3/4	1.93	2.93	3.94	5.97	8.00	2.03
0.74	8 7/8	1.97	2.99	4.02	6.09	8.17	2.08
0.75	9	2.01	3.05	4.10	6.21	8.33	2.12
0.76	9 1/8	2.05	3.11	4.18	6.33	8.49	2.16
0.77	9 1/4	2.09	3.17	4.26	6.45	8.66	2.21
0.78	9 3/8	2.13	3.23	4.34	6.58	8.82	2.24
0.79	9 1/2	2.17	3.29	4.42	6.70	8.99	2.29
0.80	9 5/8	2.21	3.35	4.51	6.83	9.16	2.33
0.81	9 3/4	2.25	3.41	4.59	6.95	9.33	2.38
0.82	9 13/16	2.29	3.47	4.67	7.08	9.50	2.42
0.83	9 15/16	2.33	3.54	4.75	7.21	9.67	2.46
0.84	10 1/16	2.37	3.60	4.84	7.33	9.84	2.51
0.85	10 3/16	2.41	3.66	4.92	7.46	10.01	2.55
0.86	10 5/16	2.46	3.72	5.01	7.59	10.19	2.60
0.87	10 7/16	2.50	3.79	5.10	7.72	10.36	2.64
0.88	10 9/16	2.54	3.85	5.18	7.85	10.54	2.69
0.89	10 11/16	2.58	3.92	5.27	7.99	10.71	2.72
0.90	10 13/16	2.62	3.98	5.35	8.12	10.89	2.77
0.91	10 15/16	2.67	4.05	5.44	8.25	11.07	2.82
0.92	11 1/16	2.71	4.11	5.53	8.38	11.25	2.87
0.93	11 3/16	2.75	4.18	5.62	8.52	11.43	2.91
0.94	11 1/4	2.79	4.24	5.71	8.65	11.61	2.96
0.95	11 3/8	2.84	4.31	5.80	8.79	11.79	3.00
0.96	11 1/2	2.88	4.37	5.89	8.93	11.98	3.05
0.97	11 5/8	2.93	4.44	5.98	9.06	12.16	3.10
0.98	11 3/4	2.97	4.51	6.07	9.20	12.34	3.14
0.99	11 7/8	3.01	4.57	6.15	9.34	12.53	3.19
1.00	12	3.06	4.64	6.25	9.48	12.72	3.24
1.01	12 1/8	......	4.71	6.34	9.62	12.91	3.29
1.02	12 1/4	......	4.78	6.43	9.76	13.10	3.34
1.03	12 3/8	......	4.85	6.52	9.90	13.28	3.38
1.04	12 1/2	......	4.92	6.62	10.04	13.47	3.43
1.05	12 5/8	......	4.98	6.71	10.18	13.66	3.48
1.06	12 3/4	......	5.05	6.80	10.32	13.85	3.53
1.07	12 13/16	......	5.12	6.90	10.46	14.04	3.58
1.08	12 15/16	......	5.20	6.99	10.61	14.24	3.63
1.09	13 1/16	......	5.26	7.09	10.75	14.43	3.68
1.10	13 3/16	......	5.34	7.19	10.90	14.64	3.74
1.11	13 5/16	......	5.41	7.28	11.04	14.83	3.79
1.12	13 7/16	......	5.48	7.38	11.19	15.03	3.84
1.13	13 9/16	......	5.55	7.47	11.34	15.22	3.88
1.14	13 11/16	......	5.62	7.57	11.48	15.42	3.94
1.15	13 13/16	......	5.69	7.66	11.64	15.62	3.98
1.16	13 15/16	......	5.77	7.76	11.79	15.82	4.03
1.17	14 1/16	......	5.84	7.86	11.94	16.02	4.08
1.18	14 3/16	......	5.91	7.96	12.09	16.23	4.14
1.19	14 1/4	......	5.98	8.06	12.24	16.43	4.19
1.20	14 3/8	......	6.06	8.16	12.39	16.63	4.24
1.21	14 1/2	......	6.13	8.26	12.54	16.83	4.29
1.22	14 5/8	......	6.20	8.35	12.69	17.03	4.34
1.23	14 3/4	......	6.28	8.46	12.85	17.25	4.40
1.24	14 7/8	......	6.35	8.56	12.99	17.45	4.46
1.25	15	......	6.43	8.66	13.14	17.65	4.51
1.26	15 1/8	......	......	......	13.30	17.87	4.57
1.27	15 1/4	......	......	......	13.45	18.07	4.62
1.28	15 3/8	......	......	......	13.61	18.28	4.67
1.29	15 1/2	......	......	......	13.77	18.50	4.73

TABLE NO. 1—*Continued*

Head in feet "H"	Head in inches, approx.	Crest Length (L) (Flow in cubic feet per second) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
1.30	15 5/8	......	......	......	13.93	18.71	4.78
1.31	15 3/4	......	......	......	14.09	18.92	4.82
1.32	15 13/16	......	......	......	14.24	19.12	4.88
1.33	15 15/16	......	......	......	14.40	19.34	4.94
1.34	16 1/16	......	......	......	14.56	19.55	4.99
1.35	16 3/16	......	......	......	14.72	19.77	5.05
1.36	16 5/16	......	......	......	14.88	19.98	5.10
1.37	16 7/16	......	......	......	15.04	20.20	5.16
1.38	16 9/16	......	......	......	15.20	20.42	5.22
1.39	16 11/16	......	......	......	15.36	20.64	5.28
1.40	16 13/16	......	......	......	15.53	20.86	5.33
1.41	16 15/16	......	......	......	15.69	21.08	5.39
1.42	17 1/16	......	......	......	15.85	21.29	5.44
1.43	17 3/16	......	......	......	16.02	21.52	5.50
1.44	17 1/4	......	......	......	16.19	21.74	5.55
1.45	17 3/8	......	......	......	16.34	21.96	5.62
1.46	17 1/2	......	......	......	16.51	22.18	5.67
1.47	17 5/8	......	......	......	16.68	22.41	5.73
1.48	17 3/4	......	......	......	16.85	22.64	5.79
1.49	17 7/8	......	......	......	17.01	22.85	5.84
1.50	18	......	......	......	17.17	23.08	5.91

TABLE 2
Flow Over Cipolletti Weirs in Cubic Feet per Second*

Head in feet "H"	Head in inches, approx.	Crest Length (L) (Flow in cubic feet per second) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
0.10	1 3/16	0.107	0.160	0.214	0.321	0.429	0.108
0.11	1 5/16	0.123	0.185	0.246	0.370	0.494	0.124
0.12	1 7/16	0.140	0.210	0.280	0.421	0.562	0.141
0.13	1 9/16	0.158	0.237	0.316	0.474	0.632	0.159
0.14	1 11/16	0.177	0.264	0.352	0.528	0.706	0.177
0.15	1 13/16	0.195	0.293	0.390	0.586	0.782	0.196
0.16	1 15/16	0.216	0.322	0.430	0.644	0.860	0.216
0.17	2 1/16	0.237	0.353	0.470	0.705	0.941	0.236
0.18	2 3/16	0.258	0.384	0.512	0.768	1.024	0.257
0.19	2 1/4	0.280	0.417	0.555	0.832	1.110	0.278
0.20	2 3/8	0.302	0.450	0.599	0.898	1.20	0.302
0.21	2 1/2	0.324	0.484	0.644	0.966	1.29	0.324
0.22	2 5/8	0.349	0.519	0.691	1.04	1.38	0.35
0.23	2 3/4	0.374	0.555	0.739	1.11	1.47	0.37
0.24	2 7/8	0.397	0.591	0.786	1.18	1.57	0.39
0.25	3	0.423	0.628	0.836	1.25	1.67	0.42
0.26	3 1/8	0.449	0.667	0.886	1.33	1.77	0.44
0.27	3 1/4	0.475	0.705	0.937	1.40	1.87	0.47
0.28	3 3/8	0.502	0.745	0.990	1.48	1.97	0.49
0.29	3 1/2	0.529	0.785	1.04	1.56	2.08	0.52
0.30	3 5/8	0.557	0.827	1.10	1.64	2.19	0.55
0.31	3 3/4	0.586	0.869	1.15	1.73	2.30	0.57
0.32	3 13/16	0.615	0.911	1.21	1.81	2.41	0.60
0.33	3 15/16	0.644	0.954	1.27	1.89	2.52	0.62
0.34	4 1/16	0.675	1.00	1.32	1.98	2.64	0.66
0.35	4 3/16	0.705	1.04	1.38	2.07	2.75	0.69
0.36	4 5/16	0.735	1.09	1.44	2.16	2.87	0.71
0.37	4 7/16	0.767	1.13	1.50	2.25	2.99	0.74
0.38	4 9/16	0.799	1.18	1.57	2.34	3.11	0.78
0.39	4 11/16	0.832	1.23	1.63	2.43	3.24	0.81
0.40	4 13/16	0.866	1.28	1.69	2.53	3.36	0.84
0.41	4 15/16	0.899	1.32	1.76	2.62	3.49	0.87
0.42	5 1/16	0.932	1.37	1.82	2.72	3.61	0.89
0.43	5 3/16	0.967	1.42	1.89	2.81	3.74	0.93
0.44	5 1/4	1.00	1.47	1.95	2.91	3.87	0.97
0.45	5 3/8	1.04	1.53	2.02	3.01	4.01	1.00
0.46	5 1/2	1.07	1.58	2.09	3.11	4.14	1.02
0.47	5 5/8	1.11	1.63	2.16	3.21	4.28	1.06
0.48	5 3/4	1.15	1.68	2.23	3.32	4.41	1.10
0.49	5 7/8	1.18	1.74	2.30	3.42	4.55	1.13
0.50	6	1.22	1.79	2.37	3.53	4.69	1.16
0.51	6 1/8	1.26	1.85	2.44	3.64	4.83	1.20
0.52	6 1/4	1.30	1.90	2.51	3.74	4.97	1.24
0.53	6 3/8	1.34	1.96	2.59	3.85	5.12	1.26
0.54	6 1/2	1.38	2.02	2.66	3.96	5.26	1.30
0.55	6 5/8	1.42	2.07	2.74	4.07	5.41	1.33
0.56	6 3/4	1.46	2.13	2.81	4.18	5.56	1.38
0.57	6 13/16	1.50	2.19	2.89	4.30	5.71	1.41
0.58	6 15/16	1.54	2.25	2.97	4.41	5.86	1.44
0.59	7 1/16	1.58	2.31	3.05	4.53	6.01	1.49
0.60	7 3/16	1.62	2.37	3.13	4.64	6.17	1.53
0.61	7 5/16	1.67	2.43	3.20	4.76	6.32	1.55
0.62	7 7/16	1.71	2.49	3.28	4.88	6.47	1.60
0.63	7 9/16	1.75	2.55	3.37	5.00	6.63	1.63
0.64	7 11/16	1.80	2.62	3.45	5.12	6.79	1.67
0.65	7 13/16	1.84	2.68	3.53	5.24	6.95	1.72
0.66	7 15/16	1.89	2.75	3.61	5.36	7.11	1.75
0.67	8 1/16	1.93	2.81	3.70	5.48	7.28	1.79
0.68	8 3/16	1.98	2.87	3.79	5.61	7.44	1.83
0.69	8 1/4	2.02	2.94	3.87	5.73	7.61	1.87
0.70	8 3/8	2.07	3.01	3.95	5.86	7.77	1.91
0.71	8 1/2	2.12	3.07	4.04	5.99	7.94	1.95
0.72	8 5/8	2.16	3.14	4.13	6.12	8.11	1.99
0.73	8 3/4	2.21	3.21	4.22	6.24	8.28	2.03
0.74	8 7/8	2.26	3.28	4.31	6.38	8.45	2.08

*Computed from Cone's formula. For field computation use Cipolletti's formula.

TABLE NO. 2—*Continued*

Head in feet "H"	Head in inches, approx.	Crest Length (L) (Flow in cubic feet per second) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
0.75	9	2.31	3.35	4.40	6.51	8.62	2.12
0.76	9 1/8	2.36	3.42	4.49	6.64	8.80	2.16
0.77	9 1/4	2.41	3.49	4.58	6.77	8.97	2.21
0.78	9 3/8	2.46	3.56	4.67	6.90	9.15	2.24
0.79	9 1/2	2.51	3.63	4.76	7.04	9.33	2.29
0.80	9 5/8	2.56	3.70	4.85	7.18	9.51	2.33
0.81	9 3/4	2.61	3.77	4.95	7.31	9.69	2.38
0.82	9 13/16	2.66	3.84	5.04	7.45	9.87	2.42
0.83	9 15/16	2.71	3.92	5.14	7.59	10.05	2.46
0.84	10 1/16	2.77	3.99	5.23	7.73	10.23	2.51
0.85	10 3/16	2.82	4.07	5.33	7.87	10.42	2.55
0.86	10 5/16	2.87	4.14	5.43	8.01	10.60	2.60
0.87	10 7/16	2.93	4.22	5.52	8.15	10.79	2.64
0.88	10 9/16	2.98	4.29	5.62	8.30	10.98	2.69
0.89	10 11/16	3.04	4.37	5.72	8.44	11.17	2.72
0.90	10 13/16	3.09	4.45	5.82	8.59	11.36	2.77
0.91	10 15/16	3.15	4.53	5.92	8.73	11.55	2.82
0.92	11 1/16	3.20	4.60	6.02	8.88	11.74	2.87
0.93	11 3/16	3.26	4.68	6.13	9.03	11.94	2.91
0.94	11 1/4	3.32	4.76	6.23	9.17	12.13	2.96
0.95	11 3/8	3.37	4.84	6.33	9.32	12.33	3.00
0.96	11 1/2	3.43	4.92	6.44	9.48	12.53	3.05
0.97	11 5/8	3.49	5.00	6.55	9.62	12.72	3.10
0.98	11 3/4	3.55	5.09	6.64	9.78	12.92	3.14
0.99	11 7/8	3.61	5.17	6.75	9.93	13.12	3.19
1.00	12	3.67	5.25	6.86	10.08	13.32	3.24
1.01	12 1/8	......	5.33	6.96	10.24	13.53	3.29
1.02	12 1/4	......	5.42	7.07	10.40	13.73	3.34
1.03	12 3/8	......	5.50	7.18	10.55	13.94	3.38
1.04	12 1/2	......	5.59	7.29	10.71	14.15	3.43
1.05	12 5/8	......	5.67	7.40	10.87	14.35	3.48
1.06	12 3/4	......	5.76	7.51	11.03	14.56	3.53
1.07	12 13/16	......	5.84	7.62	11.18	14.76	3.58
1.08	12 15/16	......	5.93	7.73	11.35	14.98	3.63
1.09	13 1/16	......	6.02	7.84	11.51	15.19	3.68
1.10	13 3/16	......	6.11	7.96	11.68	15.41	3.74
1.11	13 5/16	......	6.20	8.07	11.84	15.62	3.79
1.12	13 7/16	......	6.29	8.18	12.00	15.84	3.84
1.13	13 9/16	......	6.37	8.29	12.16	16.04	3.88
1.14	13 11/16	......	6.46	8.41	12.33	16.26	3.94
1.15	13 13/16	......	6.56	8.53	12.50	16.48	3.98
1.16	13 15/16	......	6.65	8.65	12.67	16.70	4.03
1.17	14 1/16	......	6.74	8.76	12.84	16.93	4.08
1.18	14 3/16	......	6.83	8.88	13.01	17.15	4.14
1.19	14 1/4	......	6.93	9.00	13.18	17.37	4.19
1.20	14 3/8	......	7.02	9.12	13.35	17.59	4.24
1.21	14 1/2	......	7.11	9.24	13.52	17.81	4.29
1.22	14 5/8	......	7.20	9.36	13.69	18.03	4.34
1.23	14 3/4	......	7.30	9.48	13.87	18.27	4.40
1.24	14 7/8	......	7.40	9.60	14.04	18.49	4.46
1.25	15	......	7.49	9.72	14.21	18.71	4.51
1.26	15 1/8	......	......	......	14.39	18.95	4.57
1.27	15 1/4	......	......	......	14.56	19.17	4.62
1.28	15 3/8	......	......	......	14.74	19.41	4.67
1.29	15 1/2	......	......	......	19.92	19.65	4.73
1.30	15 5/8	......	......	......	15.11	19.88	4.78
1.31	15 3/4	......	......	......	15.29	20.12	4.82
1.32	15 13/16	......	......	......	15.46	20.34	4.88
1.33	15 15/16	......	......	......	15.64	20.58	4.94
1.34	16 1/16	......	......	......	15.82	20.82	4.99
1.35	16 3/16	......	......	......	16.01	21.06	5.05
1.36	16 5/16	......	......	......	16.19	21.29	5.10
1.37	16 7/16	......	......	......	16.37	21.53	5.16
1.38	16 9/16	......	......	......	16.57	21.78	5.22
1.39	16 11/16	......	......	......	16.75	22.02	5.28

TABLE No. 2—*Continued*

Head in feet "H"	Head in inches, approx.	Crest Length (L) (Flow in cubic feet per second) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
1.40	16 13/16	—	—	—	16.94	22.27	5.33
1.41	16 15/16	—	—	—	17.13	22.51	5.39
1.42	17 1/16	—	—	—	17.31	22.75	5.44
1.43	17 3/16	—	—	—	17.51	23.01	5.50
1.44	17 1/4	—	—	—	17.70	23.26	5.55
1.45	17 3/8	—	—	—	17.89	23.50	5.62
1.46	17 1/2	—	—	—	18.08	23.75	5.67
1.47	17 5/8	—	—	—	18.28	24.01	5.73
1.48	17 3/4	—	—	—	18.47	24.26	5.79
1.49	17 7/8	—	—	—	18.66	24.50	5.84
1.50	18	—	—	—	18.85	24.75	5.91

TABLE 3

Flow Over 90-Degree Triangular-Notch Weir in Cubic Feet per Second and Gallons per Minute*

Head in feet "H"	Head in inches approximately	Flow in cubic feet per second	Flow in gallons per minute
0.10	1 3/16	0.008	3.6
0.11	1 5/16	0.010	4.5
0.12	1 7/16	0.012	5.4
0.13	1 9/16	0.016	7.2
0.14	1 11/16	0.019	8.5
0.15	1 13/16	0.022	9.9
0.16	1 15/16	0.026	11.7
0.17	2 1/16	0.031	13.9
0.18	2 3/16	0.035	15.7
0.19	2 1/4	0.040	18.0
0.20	2 3/8	0.046	20.6
0.21	2 1/2	0.052	23.3
0.22	2 5/8	0.058	26.0
0.23	2 3/4	0.065	29.2
0.24	2 7/8	0.072	32.3
0.25	3	0.080	35.9
0.26	3 1/8	0.088	39.5
0.27	3 1/4	0.096	43.1
0.28	3 3/8	0.106	47.6
0.29	3 1/2	0.115	51.6
0.30	3 5/8	0.125	56.1
0.31	3 3/4	0.136	61.0
0.32	3 13/16	0.147	66.0
0.33	3 15/16	0.159	71.4
0.34	4 1/16	0.171	76.7
0.35	4 3/16	0.184	82.6
0.36	4 5/16	0.197	88.4
0.37	4 7/16	0.211	94.7
0.38	4 9/16	0.226	*101.0
0.39	4 11/16	0.240	108.0
0.40	4 13/16	0.256	115
0.41	4 15/16	0.272	122
0.42	5 1/16	0.289	130
0.43	5 3/16	0.306	137
0.44	5 1/4	0.324	145
0.45	5 3/8	0.343	154
0.46	5 1/2	0.362	162
0.47	5 5/8	0.382	171
0.48	5 3/4	0.403	181
0.49	5 7/8	0.424	190
0.50	6	0.445	200
0.51	6 1/8	0.468	210
0.52	6 1/4	0.491	220
0.53	6 3/8	0.515	231
0.54	6 1/2	0.539	242
0.55	6 5/8	0.564	253
0.56	6 3/4	0.590	265
0.57	6 13/16	0.617	277
0.58	6 15/16	0.644	289
0.59	7 1/16	0.672	302
0.60	7 3/16	0.700	314
0.61	7 5/16	0.730	328
0.62	7 7/16	0.760	341
0.63	7 9/16	0.790	355
0.64	7 11/16	0.822	369
0.65	7 13/16	0.854	383
0.66	7 15/16	0.887	398
0.67	8 1/16	0.921	413
0.68	8 3/16	0.955	429
0.69	8 1/4	0.991	445
0.70	8 3/8	1.03	462
0.71	8 1/2	1.06	476
0.72	8 5/8	1.10	494
0.73	8 3/4	1.14	512
0.74	8 7/8	1.18	530

Computed from Cone's formulas. For field computation use Thompson's formula.
***Computed to nearest gallon.**

TABLE NO. 3—*Continued*

Head in feet "H"	Head in inches approximately	Flow in cubic feet per second	Flow in gallons per minute
0.75	9	1.22	548
0.76	9 1/8	1.26	566
0.77	9 1/4	1.30	583
0.78	9 3/8	1.34	601
0.79	9 1/2	1.39	624
0.80	9 5/8	1.43	642
0.81	9 3/4	1.48	664
0.82	9 13/16	1.52	682
0.83	9 15/16	1.57	705
0.84	10 1/16	1.61	723
0.85	10 3/16	1.66	745
0.86	10 5/16	1.71	767
0.87	10 7/16	1.76	790
0.88	10 9/16	1.81	812
0.89	10 11/16	1.86	835
0.90	10 13/16	1.92	862
0.91	10 15/16	1.97	884
0.92	11 1/16	2.02	907
0.93	11 3/16	2.08	934
0.94	11 1/4	2.13	956
0.95	11 3/8	2.19	983
0.96	11 1/2	2.25	1,010
0.97	11 5/8	2.31	1,037
0.98	11 3/4	2.37	1,064
0.99	11 7/8	2.43	1,091
1.00	12	2.49	1,118
1.01	12 1/8	2.55	1,145
1.02	12 1/4	2.61	1,171
1.03	12 3/8	2.68	1,203
1.04	12 1/2	2.74	1,230
1.05	12 5/8	2.81	1,261
1.06	12 3/4	2.87	1,288
1.07	12 13/16	2.94	1,320
1.08	12 15/16	3.01	1,351
1.09	13 1/16	3.08	1,382
1.10	13 3/16	3.15	1,414
1.11	13 5/16	3.22	1,445
1.12	13 7/16	3.30	1,481
1.13	13 9/16	3.37	1,513
1.14	13 11/16	3.44	1,544
1.15	13 13/16	3.52	1,580
1.16	13 15/16	3.59	1,611
1.17	14 1/16	3.67	1,647
1.18	14 3/16	3.75	1,683
1.19	14 1/4	3.83	1,719
1.20	14 3/8	3.91	1,755
1.21	14 1/2	3.99	1,791
1.22	14 5/8	4.07	1,827
1.23	14 3/4	4.16	1,867
1.24	14 7/8	4.24	1,903
1.25	15	4.33	1,943

TABLE 4
Flow Over Rectangular Suppressed Weirs in Cubic Feet per Second*

Head, in feet	Head in inches approx.	WEIR HEIGHT — Flow in cubic feet per second per foot of weir crest						
		0.5 foot	0.75 foot	1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet
0.10	1 3/16	0.111	0.110	0.109	0.109	0.108	0.108	0.108
0.11	1 5/16	0.127	0.126	0.126	0.125	0.125	0.125	0.124
0.12	1 7/16	0.145	0.144	0.143	0.142	0.142	0.141	0.141
0.13	1 9/16	0.163	0.162	0.161	0.160	0.159	0.159	0.159
0.14	1 11/16	0.182	0.180	0.179	0.178	0.178	0.177	0.177
0.15	1 13/16	0.202	0.200	0.199	0.197	0.197	0.196	0.196
0.16	1 15/16	0.223	0.220	0.219	0.217	0.216	0.216	0.215
0.17	2 1/16	0.244	0.241	0.239	0.238	0.237	0.236	0.235
0.18	2 3/16	0.266	0.263	0.261	0.259	0.257	0.257	0.256
0.19	2 1/4	0.289	0.285	0.283	0.280	0.279	0.277	0.277
0.20	2 3/8	0.312	0.307	0.305	0.302	0.300	0.299	0.299
0.21	2 1/2	0.336	0.331	0.328	0.325	0.324	0.322	0.322
0.22	2 5/8	0.361	0.355	0.352	0.349	0.347	0.345	0.344
0.23	2 3/4	0.387	0.386	0.376	0.372	0.370	0.369	0.368
0.24	2 7/8	0.413	0.406	0.401	0.397	0.395	0.393	0.392
0.25	3	0.440	0.431	0.427	0.422	0.420	0.418	0.416
0.26	3 1/8	0.467	0.458	0.452	0.447	0.445	0.442	0.442
0.27	3 1/4	0.495	0.485	0.479	0.473	0.471	0.468	0.467
0.28	3 3/8	0.524	0.513	0.506	0.500	0.498	0.495	0.493
0.29	3 1/2	0.554	0.541	0.535	0.527	0.524	0.521	0.520
0.30	3 5/8	0.583	0.569	0.562	0.555	0.552	0.548	0.545
0.31	3 11/16	0.614	0.599	0.591	0.583	0.580	0.576	0.574
0.32	3 13/16	0.645	0.629	0.620	0.612	0.608	0.604	0.602
0.33	3 15/16	0.677	0.659	0.650	0.641	0.637	0.633	0.631
0.34	4 1/16	0.709	0.690	0.681	0.670	0.666	0.662	0.660
0.35	4 3/16	0.742	0.722	0.711	0.701	0.696	0.691	0.688
0.36	4 5/16	0.775	0.754	0.743	0.731	0.725	0.721	0.717
0.37	4 7/16	0.810	0.787	0.774	0.762	0.757	0.751	0.748
0.38	4 9/16	0.844	0.819	0.807	0.793	0.788	0.782	0.778
0.39	4 11/16	0.881	0.853	0.840	0.826	0.819	0.813	0.809
0.40	4 13/16	0.916	0.888	0.873	0.858	0.851	0.844	0.840
0.41	4 15/16	0.952	0.922	0.907	0.890	0.883	0.876	0.872
0.42	5 1/16	0.990	0.958	0.942	0.924	0.917	0.908	0.904
0.43	5 1/8	1.03	0.994	0.976	0.958	0.950	0.941	0.937
0.44	5 1/4	1.07	1.03	1.01	0.993	0.983	0.974	0.969
0.45	5 3/8	1.10	1.07	1.05	1.03	1.02	1.01	1.00
0.46	5 1/2	1.14	1.10	1.08	1.06	1.05	1.04	1.04
0.47	5 5/8	1.18	1.14	1.12	1.10	1.09	1.08	1.07
0.48	5 3/4	1.22	1.18	1.16	1.13	1.12	1.11	1.10
0.49	5 7/8	1.27	1.22	1.19	1.17	1.16	1.15	1.14
0.50	6	1.31	1.26	1.23	1.21	1.20	1.18	1.18
0.51	6 1/8	1.35	1.30	1.27	1.24	1.23	1.22	1.21
0.52	6 1/4	1.39	1.34	1.31	1.28	1.27	1.25	1.25
0.53	6 3/8	1.44	1.38	1.35	1.32	1.30	1.29	1.28
0.54	6 1/2	1.48	1.42	1.39	1.36	1.34	1.33	1.32
0.55	6 5/8	1.52	1.46	1.43	1.40	1.38	1.36	1.36
0.56	6 3/4	1.57	1.50	1.47	1.44	1.42	1.40	1.39
0.57	6 13/16	1.61	1.54	1.51	1.48	1.46	1.44	1.43
0.58	6 15/16	1.66	1.59	1.55	1.52	1.50	1.48	1.47
0.59	7 1/16	1.71	1.63	1.60	1.56	1.54	1.52	1.51
0.60	7 3/16	1.76	1.68	1.64	1.60	1.58	1.56	1.55
0.61	7 5/16	1.80	1.72	1.68	1.64	1.62	1.59	1.58
0.62	7 7/16	1.85	1.77	1.72	1.68	1.66	1.63	1.62
0.63	7 9/16	1.90	1.81	1.77	1.72	1.70	1.68	1.67
0.64	7 11/16	1.95	1.86	1.81	1.76	1.74	1.72	1.71
0.65	7 13/16	2.00	1.90	1.86	1.81	1.78	1.76	1.75
0.66	7 15/16	2.05	1.95	1.90	1.85	1.82	1.80	1.79
0.67	8 1/16	2.10	2.00	1.95	1.90	1.87	1.84	1.83
0.68	8 3/16	2.15	2.05	1.99	1.94	1.91	1.88	1.87
0.69	8 1/4	2.21	2.09	2.04	1.98	1.95	1.93	1.91
0.70	8 3/8	2.26	2.14	2.08	2.03	2.00	1.97	1.95
0.71	8 1/2	2.31	2.19	2.13	2.07	2.04	2.01	2.00
0.72	8 5/8	2.37	2.24	2.18	2.12	2.08	2.05	2.04
0.73	8 3/4	2.42	2.29	2.23	2.16	2.13	2.10	2.08
0.74	8 7/8	2.48	2.34	2.28	2.21	2.18	2.14	2.12

*Computed from the simplified form of Rehbock's formula. For field computation use Francis's formula.

TABLE No. 4—*Continued*

Head, in feet	Head in inches approx.	Weir Height — Flow in cubic feet per second per foot of weir crest: 0.5 foot	0.75 foot	1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet
0.75	9	2.53	2.39	2.32	2.25	2.22	2.18	2.17
0.76	9⅛	2.59	2.45	2.37	2.30	2.27	2.23	2.21
0.77	9¼	2.65	2.50	2.43	2.35	2.31	2.27	2.26
0.78	9⅜	2.70	2.55	2.48	2.40	2.36	2.32	2.30
0.79	9½	2.76	2.60	2.52	2.45	2.41	2.37	2.35
0.80	9⅝	2.82	2.66	2.58	2.49	2.45	2.41	2.39
0.81	9¾	2.88	2.71	2.63	2.54	2.50	2.46	2.44
0.82	9 13/16	2.94	2.76	2.68	2.59	2.55	2.51	2.48
0.83	9 15/16	3.00	2.82	2.73	2.64	2.60	2.55	2.53
0.84	10 1/16	3.06	2.87	2.78	2.69	2.64	2.60	2.58
0.85	10 3/16	3.12	2.93	2.84	2.74	2.69	2.65	2.62
0.86	10 5/16	3.18	2.99	2.89	2.79	2.74	2.69	2.67
0.87	10 7/16	3.25	3.04	2.94	2.84	2.80	2.74	2.72
0.88	10 9/16	3.31	3.10	3.00	2.90	2.84	2.79	2.76
0.89	10 11/16	3.37	3.16	3.05	2.95	2.89	2.84	2.81
0.90	10 13/16	3.43	3.22	3.11	3.00	2.95	2.89	2.86
0.91	10 15/16	3.50	3.27	3.16	3.05	2.99	2.94	2.91
0.92	11 1/16	3.57	3.34	3.22	3.11	3.04	2.99	2.96
0.93	11 3/16	3.63	3.40	3.28	3.16	3.10	3.04	3.01
0.94	11¼	3.70	3.46	3.33	3.21	3.15	3.09	3.06
0.95	11⅜	3.76	3.52	3.39	3.26	3.20	3.14	3.11
0.96	11½	3.83	3.58	3.45	3.32	3.26	3.19	3.16
0.97	11⅝	3.90	3.64	3.51	3.37	3.31	3.24	3.21
0.98	11¾	3.97	3.70	3.57	3.42	3.36	3.29	3.26
0.99	11⅞	4.04	3.76	3.62	3.48	3.41	3.35	3.31
1.00	12	4.11	3.82	3.68	3.54	3.47	3.40	3.36
1.01	12⅛	......	3.89	3.74	3.59	3.52	3.45	3.41
1.02	12¼	......	3.95	3.80	3.65	3.58	3.50	3.47
1.03	12⅜	......	4.01	3.86	3.71	3.63	3.56	3.52
1.04	12½	......	4.08	3.93	3.77	3.69	3.61	3.57
1.05	12⅝	......	4.14	3.98	3.82	3.74	3.66	3.62
1.06	12¾	......	4.21	4.04	3.88	3.80	3.71	3.67
1.07	12 13/16	......	4.27	4.11	3.94	3.85	3.77	3.73
1.08	12 15/16	......	4.34	4.17	4.00	3.91	3.82	3.78
1.09	13 1/16	......	4.41	4.24	4.05	3.97	3.88	3.83
1.10	13 3/16	......	4.48	4.30	4.12	4.02	3.93	3.89
1.11	13 5/16	......	4.54	4.36	4.17	4.09	3.99	3.94
1.12	13 7/16	......	4.61	4.42	4.23	4.14	4.04	3.99
1.13	13 9/16	......	4.68	4.49	4.29	4.19	4.10	4.05
1.14	13 11/16	......	4.75	4.55	4.36	4.26	4.15	4.11
1.15	13 13/16	......	4.82	4.62	4.41	4.31	4.21	4.16
1.16	13 15/16	......	4.89	4.68	4.47	4.37	4.27	4.22
1.17	14 1/16	......	4.96	4.75	4.54	4.44	4.33	4.27
1.18	14 3/16	......	5.03	4.82	4.60	4.49	4.38	4.33
1.19	14¼	......	5.10	4.88	4.67	4.55	4.44	4.39
1.20	14⅜	......	5.17	4.95	4.72	4.61	4.50	4.44
1.21	14½	......	5.25	5.02	4.79	4.67	4.56	4.50
1.22	14⅝	......	5.32	5.09	4.85	4.73	4.61	4.56
1.23	14¾	......	5.39	5.16	4.92	4.79	4.68	4.61
1.24	14⅞	......	5.47	5.22	4.98	4.88	4.73	4.67
1.25	15	......	5.54	5.29	5.05	4.92	4.79	4.73
1.26	15⅛	......	......	5.36	5.10	4.98	4.85	4.79
1.27	15¼	......	......	5.43	5.17	5.04	4.91	4.84
1.28	15⅜	......	......	5.51	5.24	5.10	4.97	4.90
1.29	15½	......	......	5.57	5.30	5.16	5.03	4.96
1.30	15⅝	......	......	5.64	5.36	5.23	5.09	5.02
1.31	15¾	......	......	5.72	5.44	5.29	5.16	5.08
1.32	15 13/16	......	......	5.79	5.50	5.36	5.22	5.14
1.33	15 15/16	......	......	5.86	5.57	5.42	5.28	5.20
1.34	16 1/16	......	......	5.93	5.63	5.48	5.33	5.26
1.35	16 3/16	......	......	6.01	5.71	5.56	5.40	5.32
1.36	16 5/16	......	......	6.08	5.77	5.62	5.46	5.38
1.37	16 7/16	......	......	6.15	5.84	5.68	5.52	5.45
1.38	16 9/16	......	......	6.22	5.90	5.75	5.58	5.51
1.39	16 11/16	......	......	6.30	5.98	5.81	5.65	5.57

TABLE NO. 4—*Continued*

Head, in feet	Head in inches approx.	Weir Height — Flow in cubic feet per second per foot of weir crest: 0.5 foot	0.75 foot	1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet
1.40	16 13/16	-----	-----	6.38	6.04	5.87	5.71	5.62
1.41	16 15/16	-----	-----	6.46	6.12	5.95	5.78	5.69
1.42	17 1/16	-----	-----	6.52	6.18	6.01	5.84	5.75
1.43	17 3/16	-----	-----	6.60	6.26	6.08	5.91	5.82
1.44	17 1/4	-----	-----	6.68	6.32	6.15	5.97	5.88
1.45	17 3/8	-----	-----	6.76	6.40	6.21	6.03	5.94
1.46	17 1/2	-----	-----	6.84	6.46	6.28	6.09	6.00
1.47	17 5/8	-----	-----	6.91	6.53	6.35	6.17	6.06
1.48	17 3/4	-----	-----	6.99	6.60	6.41	6.23	6.12
1.49	17 7/8	-----	-----	7.07	6.68	6.49	6.29	6.20
1.50	18	-----	-----	7.15	6.75	6.56	6.36	6.26

TABLE 5

Flow Through Rectangular Submerged Orifices in Cubic Feet per Second*

Head, in feet "H"	Head, in inches, approx.	Cross-Sectional Area of Orifice, A — Flow in cubic feet per second: 0.25 sq. ft.	0.333 sq. ft.	0.50 sq. ft.	0.75 sq. ft.	1.00 sq. ft.	1.50 sq. ft.	2.00 sq. ft.
0.01	1/8	0.122	0.163	0.245	0.367	0.489	0.73	0.98
0.02	1/4	0.173	0.230	0.346	0.518	0.691	1.04	1.38
0.03	3/8	0.212	0.282	0.424	0.635	0.847	1.27	1.69
0.04	1/2	0.245	0.326	0.489	0.734	0.978	1.47	1.96
0.05	5/8	0.273	0.364	0.547	0.820	1.09	1.64	2.19
0.06	3/4	0.300	0.399	0.599	0.899	1.20	1.80	2.40
0.07	13/16	0.324	0.431	0.647	0.971	1.29	1.94	2.59
0.08	15/16	0.346	0.461	0.691	1.04	1.38	2.07	2.77
0.09	1 1/16	0.367	0.489	0.734	1.10	1.47	2.20	2.94
0.10	1 3/16	0.387	0.518	0.773	1.16	1.56	2.32	3.09
0.11	1 5/16	0.406	0.540	0.811	1.22	1.62	2.43	3.24
0.12	1 7/16	0.424	0.564	0.847	1.27	1.69	2.54	3.39
0.13	1 9/16	0.441	0.587	0.882	1.32	1.76	2.65	3.53
0.14	1 11/16	0.458	0.609	0.915	1.37	1.83	2.75	3.66
0.15	1 13/16	0.474	0.631	0.947	1.42	1.90	2.84	3.79
0.16	1 15/16	0.489	0.651	0.978	1.47	1.96	2.93	3.91
0.17	2 1/16	0.504	0.671	1.01	1.51	2.02	3.02	4.03
0.18	2 3/16	0.519	0.691	1.04	1.56	2.08	3.11	4.15
0.19	2 1/4	0.533	0.710	1.07	1.60	2.13	3.20	4.26
0.20	2 3/8	0.547	0.729	1.09	1.64	2.19	3.28	4.38
0.21	2 1/2	0.561	0.746	1.12	1.68	2.24	3.36	4.48
0.22	2 5/8	0.574	0.765	1.15	1.72	2.30	3.46	4.59
0.23	2 3/4	0.587	0.781	1.17	1.76	2.35	3.52	4.69
0.24	2 7/8	0.600	0.798	1.20	1.80	2.40	3.60	4.79
0.25	3	0.612	0.815	1.22	1.83	2.45	3.67	4.89
0.26	3 1/8	0.624	0.831	1.25	1.87	2.49	3.74	4.99
0.27	3 1/4	0.636	0.846	1.27	1.91	2.54	3.81	5.08
0.28	3 3/8	0.646	0.862	1.29	1.94	2.59	3.88	5.18
0.29	3 1/2	0.659	0.878	1.32	1.98	2.64	3.96	5.28
0.30	3 5/8	0.670	0.892	1.34	2.01	2.68	4.02	5.36
0.31	3 3/4	0.681	0.908	1.36	2.05	2.73	4.09	5.45
0.32	3 13/16	0.692	0.920	1.38	2.07	2.76	4.15	5.53
0.33	3 15/16	0.703	0.936	1.41	2.11	2.81	4.22	5.62
0.34	4 1/16	0.713	0.950	1.43	2.14	2.85	4.28	5.70
0.35	4 3/16	0.724	0.963	1.45	2.17	2.89	4.34	5.78
0.36	4 5/16	0.734	0.976	1.47	2.20	2.93	4.40	5.87
0.37	4 7/16	0.745	0.991	1.49	2.23	2.98	4.46	5.95
0.38	4 9/16	0.754	1.00	1.51	2.26	3.02	4.52	6.03
0.39	4 11/16	0.764	1.02	1.53	2.29	3.05	4.58	6.11
0.40	4 13/16	0.774	1.03	1.55	2.32	3.09	4.64	6.19
0.41	4 15/16	0.783	1.04	1.57	2.35	3.13	4.70	6.27
0.42	5 1/16	0.792	1.06	1.59	2.38	3.17	4.75	6.34
0.43	5 3/16	0.802	1.07	1.60	2.41	3.21	4.81	6.42
0.44	5 1/4	0.811	1.08	1.62	2.43	3.24	4.87	6.49
0.45	5 3/8	0.820	1.09	1.64	2.46	3.28	4.92	6.56
0.46	5 1/2	0.829	1.10	1.66	2.49	3.32	4.98	6.64
0.47	5 5/8	0.839	1.12	1.68	2.52	3.36	5.04	6.71
0.48	5 3/4	0.847	1.13	1.70	2.54	3.39	5.08	6.78
0.49	5 7/8	0.856	1.14	1.71	2.57	3.42	5.14	6.85
0.50	6	0.865	1.15	1.73	2.59	3.46	5.19	6.92
0.51	6 1/8	0.873	1.16	1.75	2.62	3.49	5.24	6.99
0.52	6 1/4	0.882	1.17	1.76	2.65	3.53	5.29	7.05
0.53	6 3/8	0.890	1.19	1.78	2.67	3.56	5.34	7.12
0.54	6 1/2	0.898	1.20	1.80	2.70	3.59	5.39	7.19
0.55	6 5/8	0.907	1.21	1.81	2.72	3.63	5.44	7.25
0.56	6 3/4	0.915	1.22	1.83	2.75	3.66	5.49	7.32
0.57	6 13/16	0.923	1.23	1.85	2.77	3.69	5.54	7.38
0.58	6 15/16	0.931	1.24	1.86	2.79	3.73	5.59	7.45
0.59	7 1/16	0.939	1.25	1.88	2.82	3.76	5.64	7.51
0.60	7 3/16	0.947	1.26	1.90	2.84	3.79	5.68	7.58
0.61	7 5/16	0.955	1.27	1.91	2.87	3.82	5.73	7.64
0.62	7 7/16	0.963	1.28	1.93	2.89	3.85	5.78	7.70
0.63	7 9/16	0.971	1.29	1.94	2.91	3.88	5.82	7.76
0.64	7 11/16	0.978	1.30	1.96	2.93	3.91	5.87	7.82
0.65	7 13/16	0.986	1.31	1.97	2.96	3.94	5.92	7.89

*Computed from the formula $Q = 0.61\ a \sqrt{2\ gH}$

TABLE No. 5—*Continued*

Head, in feet "H"	Head, in inches, approx.	Cross-Sectional Area of Orifice, A — Flow in cubic feet per second: 0.25 sq. ft.	0.333 sq. ft.	0.50 sq. ft.	0.75 sq. ft.	1.00 sq. ft.	1.50 sq. ft.	2.00 sq. ft.
0.66	7 15/16	0.993	1.32	1.99	2.98	3.97	5.96	7.95
0.67	8 1/16	1.00	1.33	2.00	3.00	4.00	6.01	8.01
0.68	8 3/16	1.01	1.34	2.02	3.02	4.03	6.05	8.06
0.69	8 1/4	1.02	1.35	2.03	3.05	4.06	6.10	8.13
0.70	8 3/8	1.02	1.36	2.05	3.07	4.09	6.14	8.18
0.71	8 1/2	1.03	1.37	2.06	3.09	4.12	6.19	8.25
0.72	8 5/8	1.04	1.38	2.08	3.11	4.15	6.23	8.30
0.73	8 3/4	1.05	1.39	2.09	3.14	4.18	6.27	8.36
0.74	8 7/8	1.05	1.40	2.10	3.16	4.21	6.31	8.42
0.75	9	1.06	1.41	2.12	3.18	4.24	6.36	8.48
0.76	9 1/8	1.07	1.42	2.13	3.20	4.26	6.40	8.53
0.77	9 1/4	1.07	1.43	2.15	3.22	4.29	6.43	8.58
0.78	9 3/8	1.08	1.44	2.16	3.24	4.32	6.48	8.64
0.79	9 1/2	1.09	1.45	2.17	3.26	4.35	6.52	8.70
0.80	9 5/8	1.09	1.46	2.19	3.28	4.38	6.56	8.75

TABLE 6

Velocity of Water Through Orifice Takeouts

Computed from the formula

$$V = 0.70 \sqrt{2 gH}$$

To find head take difference in level above and below opening when submerged. When water falls free take distance from upstream surface of water to center of opening.

Discharge = Area of opening × velocity.

Head and Velocity in Feet					Head and Velocity in Feet				
H	0	1	2	3	H	0	1	2	3
0.01	0.60	5.64	7.94	9.74	0.51	4.04	6.92	8.88	10.50
0.02	0.80	5.67	7.97	9.76	0.52	4.08	6.94	8.90	10.52
0.03	1.00	5.70	7.99	9.78	0.53	4.12	6.97	8.91	10.53
0.04	1.15	5.73	8.00	9.79	0.54	4.15	6.99	8.93	10.55
0.05	1.29	5.76	8.02	9.81	0.55	4.19	7.01	8.95	10.57
0.06	1.41	5.79	8.04	9.82	0.56	4.22	7.03	8.97	10.58
0.07	1.53	5.82	8.06	9.84	0.57	4.26	7.05	8.99	10.59
0.08	1.63	5.84	8.08	9.86	0.58	4.30	7.07	9.01	10.62
0.09	1.72	5.86	8.09	9.88	0.59	4.33	7.10	9.04	10.63
0.10	1.80	5.89	8.11	9.89	0.60	4.36	7.12	9.05	10.64
0.11	1.91	5.92	8.13	9.90	0.61	4.40	7.14	9.07	10.66
0.12	2.00	5.95	8.15	9.92	0.62	4.43	7.16	9.09	10.67
0.13	2.07	5.98	8.17	9.93	0.63	4.47	7.18	9.10	10.69
0.14	2.13	6.00	8.19	9.95	0.64	4.50	7.21	9.12	10.70
0.15	2.20	6.03	8.21	9.97	0.65	4.53	7.23	9.13	10.72
0.16	2.27	6.05	8.23	9.98	0.66	4.57	7.25	9.15	10.73
0.17	2.33	6.08	8.25	10.00	0.67	4.60	7.28	9.17	10.75
0.18	2.41	6.10	8.27	10.02	0.68	4.64	7.30	9.18	10.77
0.19	2.47	6.13	8.29	10.03	0.69	4.67	7.32	9.20	10.79
0.20	2.53	6.15	8.31	10.05	0.70	4.71	7.34	9.22	10.80
0.21	2.60	6.18	8.32	10.06	0.71	4.74	7.35	9.24	10.81
0.22	2.66	6.20	8.34	10.08	0.72	4.77	7.37	9.26	10.83
0.23	2.72	6.23	8.36	10.09	0.73	4.80	7.40	9.27	10.84
0.24	2.78	6.25	8.38	10.11	0.74	4.83	7.42	9.29	10.86
0.25	2.83	6.28	8.40	10.12	0.75	4.87	7.44	9.31	10.87
0.26	2.89	6.30	8.42	10.13	0.76	4.90	7.45	9.32	10.89
0.27	2.95	6.33	8.44	10.15	0.77	4.94	7.47	9.34	10.90
0.28	3.00	6.35	8.46	10.17	0.78	4.97	7.50	9.36	10.91
0.29	3.05	6.38	8.48	10.18	0.79	5.00	7.52	9.37	10.93
0.30	3.11	6.40	8.50	10.20	0.80	5.03	7.53	9.39	10.95
0.31	3.16	6.43	8.51	10.21	0.81	5.06	7.55	9.41	10.96
0.32	3.21	6.45	8.53	10.23	0.82	5.09	7.57	9.42	10.97
0.33	3.26	6.48	8.55	10.24	0.83	5.12	7.60	9.44	10.98
0.34	3.31	6.51	8.57	10.25	0.84	5.15	7.62	9.46	11.00
0.35	3.35	6.53	8.59	10.27	0.85	5.18	7.63	9.48	11.01
0.36	3.40	6.56	8.60	10.28	0.86	5.21	7.65	9.50	11.02
0.37	3.44	6.58	8.62	10.30	0.87	5.24	7.68	9.51	11.04
0.38	3.49	6.61	8.64	10.32	0.88	5.27	7.69	9.53	11.05
0.39	3.53	6.63	8.66	10.33	0.89	5.30	7.71	9.55	11.06
0.40	3.58	6.65	8.68	10.34	0.90	5.33	7.73	9.56	11.08
0.41	3.62	6.68	8.70	10.36	0.91	5.36	7.75	9.57	11.09
0.42	3.66	6.71	8.72	10.38	0.92	5.39	7.77	9.59	11.10
0.43	3.70	6.73	8.73	10.39	0.93	5.42	7.79	9.61	11.11
0.44	3.74	6.75	8.75	10.40	0.94	5.45	7.81	9.62	11.12
0.45	3.79	6.78	8.77	10.42	0.95	5.48	7.83	9.64	11.13
0.46	3.83	6.81	8.79	10.43	0.96	5.51	7.85	9.66	11.15
0.47	3.87	6.83	8.81	10.45	0.97	5.53	7.87	9.68	11.16
0.48	3.91	6.85	8.83	10.47	0.98	5.56	7.88	9.69	11.17
0.49	3.95	6.87	8.85	10.48	0.99	5.59	7.90	9.70	11.19
0.50	4.00	6.90	8.87	10.49	1.00	5.62	7.92	9.72	11.20

TABLE 7
Free-Flow Through Parshall Measuring Flumes

Upper head, Ha		Throat Width (Flow in cubic feet per second)											
Feet	Inches (approx.)	3 in.	6 in.	9 in.	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
0.10	1 3/16	0.028	0.05	0.09									
0.11	1 5/16	0.033	0.06	0.10									
0.12	1 7/16	0.037	0.07	0.12									
0.13	1 9/16	0.042	0.08	0.14									
0.14	1 11/16	0.047	0.09	0.15									
0.15	1 13/16	0.053	0.10	0.17	0.20	0.30	0.42	0.61					
0.16	1 15/16	0.058	0.11	0.19	0.23	0.34	0.47	0.68					
0.17	2 1/16	0.064	0.12	0.20	0.26	0.38	0.51	0.75					
0.18	2 3/16	0.070	0.14	0.22	0.29	0.42	0.56	0.82					
0.19	2 1/4	0.076	0.15	0.24	0.32	0.46	0.61	0.89					
0.20	2 3/8	0.082	0.16	0.26	0.35	0.51	0.66	0.97	1.26				
0.21	2 1/2	0.089	0.18	0.28	0.37	0.55	0.71	1.04	1.36				
0.22	2 5/8	0.095	0.19	0.30	0.40	0.59	0.77	1.12	1.47				
0.23	2 3/4	0.102	0.20	0.32	0.43	0.63	0.82	1.20	1.58				
0.24	2 7/8	0.109	0.22	0.35	0.46	0.67	0.88	1.28	1.69				
0.25	3	0.117	0.23	0.37	0.49	0.71	0.93	1.37	1.80	2.22	2.63	3.02	3.46
0.26	3 1/8	0.124	0.25	0.39	0.51	0.76	0.99	1.46	1.91	2.36	2.80	3.25	3.68
0.27	3 1/4	0.131	0.26	0.41	0.54	0.80	1.05	1.55	2.03	2.50	2.97	3.44	3.90
0.28	3 3/8	0.138	0.28	0.44	0.58	0.85	1.11	1.64	2.15	2.65	3.15	3.65	4.13
0.29	3 1/2	0.146	0.29	0.46	0.61	0.90	1.18	1.73	2.27	2.80	3.33	3.85	4.37
0.30	3 5/8	0.154	0.31	0.49	0.64	0.94	1.24	1.82	2.39	2.96	3.52	4.08	4.62
0.31	3 3/4	0.162	0.32	0.51	0.68	0.99	1.30	1.92	2.52	3.12	3.71	4.30	4.88
0.32	3 13/16	0.170	0.34	0.54	0.71	1.04	1.37	2.02	2.65	3.28	3.90	4.52	5.13
0.33	3 15/16	0.179	0.36	0.56	0.74	1.09	1.44	2.12	2.78	3.44	4.10	4.75	5.39
0.34	4 1/16	0.187	0.38	0.59	0.77	1.14	1.50	2.22	2.92	3.61	4.30	4.98	5.66
0.35	4 3/16	0.196	0.39	0.62	0.80	1.19	1.57	2.32	3.06	3.78	4.50	5.22	5.93
0.36	4 5/16	0.205	0.41	0.64	0.84	1.25	1.64	2.42	3.19	3.95	4.71	5.46	6.20
0.37	4 7/16	0.213	0.43	0.67	0.88	1.30	1.72	2.53	3.34	4.13	4.92	5.70	6.48
0.38	4 9/16	0.222	0.45	0.70	0.92	1.36	1.79	2.64	3.48	4.31	5.13	5.95	6.76
0.39	4 11/16	0.231	0.47	0.73	0.95	1.41	1.86	2.75	3.62	4.49	5.35	6.20	7.05
0.40	4 13/16	0.241	0.48	0.76	0.99	1.47	1.93	2.86	3.77	4.68	5.57	6.46	7.34
0.41	4 15/16	0.250	0.50	0.78	1.03	1.53	2.01	2.97	3.92	4.86	5.80	6.72	7.64
0.42	5 1/16	0.260	0.52	0.81	1.07	1.58	2.09	3.08	4.07	5.05	6.02	6.98	7.94
0.43	5 3/16	0.269	0.54	0.84	1.11	1.64	2.16	3.20	4.22	5.24	6.25	7.25	8.24
0.44	5 1/4	0.279	0.56	0.87	1.15	1.70	2.24	3.32	4.38	5.43	6.48	7.52	8.55
0.45	5 3/8	0.289	0.58	0.90	1.19	1.76	2.32	3.44	4.54	5.63	6.72	7.80	8.87
0.46	5 1/2	0.299	0.61	0.94	1.23	1.82	2.40	3.56	4.70	5.83	6.96	8.08	9.19
0.47	5 5/8	0.309	0.63	0.97	1.27	1.88	2.48	3.68	4.86	6.03	7.20	8.36	9.51
0.48	5 3/4	0.319	0.65	1.00	1.31	1.94	2.57	3.80	5.03	6.24	7.44	8.65	9.8
0.49	5 7/8	0.329	0.67	1.03	1.35	2.00	2.65	3.92	5.20	6.45	7.69	8.94	10.2
0.50	6	0.339	0.69	1.06	1.39	2.06	2.73	4.05	5.36	6.66	7.94	9.23	10.5
0.51	6 1/8	0.350	0.71	1.10	1.44	2.13	2.82	4.18	5.53	6.87	8.20	9.53	10.9
0.52	6 1/4	0.361	0.73	1.13	1.48	2.19	2.90	4.31	5.70	7.09	8.46	9.83	11.2
0.53	6 3/8	0.371	0.76	1.16	1.52	2.25	2.99	4.44	5.88	7.30	8.72	10.1	11.5
0.54	6 1/2	0.382	0.78	1.20	1.57	2.32	3.08	4.57	6.05	7.52	8.98	10.5	11.9
0.55	6 5/8	0.393	0.80	1.23	1.62	2.39	3.17	4.70	6.23	7.74	9.25	10.8	12.2
0.56	6 3/4	0.404	0.82	1.26	1.66	2.45	3.26	4.84	6.41	7.97	9.52	11.1	12.6
0.57	6 13/16	0.415	0.85	1.30	1.70	2.52	3.35	4.98	6.59	8.20	9.79	11.4	13.0
0.58	6 15/16	0.427	0.87	1.33	1.75	2.59	3.44	5.11	6.77	8.43	10.1	11.7	13.3
0.59	7 1/16	0.438	0.89	1.37	1.80	2.66	3.53	5.25	6.96	8.66	10.4	12.0	13.7
0.60	7 3/16	0.450	0.92	1.40	1.84	2.73	3.62	5.39	7.15	8.89	10.6	12.4	14.1
0.61	7 5/16	0.462	0.94	1.44	1.88	2.80	3.72	5.53	7.34	9.13	10.9	12.7	14.5
0.62	7 7/16	0.474	0.97	1.48	1.93	2.87	3.81	5.68	7.53	9.37	11.2	13.0	14.8
0.63	7 9/16	0.485	0.99	1.51	1.98	2.95	3.91	5.82	7.72	9.61	11.5	13.4	15.2
0.64	7 11/16	0.497	1.02	1.55	2.03	3.02	4.01	5.97	7.91	9.85	11.8	13.7	15.6
0.65	7 13/16	0.509	1.04	1.59	2.08	3.09	4.11	6.12	8.11	10.1	12.1	14.1	16.0
0.66	7 15/16	0.522	1.07	1.63	2.13	3.17	4.20	6.26	8.31	10.3	12.4	14.4	16.4
0.67	8 1/16	0.534	1.10	1.66	2.18	3.24	4.30	6.41	8.51	10.6	12.7	14.8	16.8
0.68	8 3/16	0.546	1.12	1.70	2.23	3.31	4.40	6.56	8.71	10.9	13.0	15.1	17.2
0.69	8 1/4	0.558	1.15	1.74	2.28	3.39	4.50	6.71	8.91	11.1	13.3	15.5	17.6

TABLE NO. 7—*Continued*

Upper head, Ha Feet	Inches (approx.)	3 in.	6 in.	9 in.	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
		THROAT WIDTH (Flow in cubic feet per second)											
0.70	8 3/8	0.571	1.17	1.78	2.33	3.46	4.60	6.86	9.11	11.4	13.6	15.8	18.0
0.71	8 1/2	0.584	1.20	1.82	2.38	3.54	4.70	7.02	9.32	11.6	13.9	16.2	18.5
0.72	8 5/8	0.597	1.23	1.86	2.43	3.62	4.81	7.17	9.53	11.9	14.2	16.6	18.9
0.73	8 3/4	0.610	1.26	1.90	2.48	3.69	4.91	7.33	9.74	12.1	14.5	16.9	19.3
0.74	8 7/8	0.623	1.28	1.94	2.53	3.77	5.02	7.49	9.95	12.4	14.9	17.3	19.7
0.75	9	....	1.31	1.98	2.58	3.85	5.12	7.65	10.2	12.7	15.2	17.7	20.1
0.76	9 1/8	....	1.34	2.02	2.63	3.93	5.23	7.81	10.4	12.9	15.5	18.0	20.6
0.77	9 1/4	....	1.36	2.06	2.68	4.01	5.34	7.97	10.6	13.2	15.8	18.4	21.0
0.78	9 3/8	....	1.39	2.10	2.74	4.09	5.44	8.13	10.8	13.5	16.2	18.8	21.5
0.79	9 1/2	....	1.42	2.14	2.80	4.17	5.55	8.30	11.0	13.8	16.5	19.2	21.9
0.80	9 5/8	....	1.45	2.18	2.85	4.26	5.66	8.46	11.3	14.0	16.8	19.6	22.4
0.81	9 3/4	....	1.48	2.22	2.90	4.34	5.77	8.63	11.5	14.3	17.2	20.0	22.8
0.82	9 13/16	....	1.50	2.27	2.96	4.42	5.88	8.79	11.7	14.6	17.5	20.4	23.3
0.83	9 15/16	....	1.53	2.31	3.02	4.50	6.00	8.96	11.9	14.9	17.8	20.8	23.7
0.84	10 1/16	....	1.56	2.35	3.07	4.59	6.11	9.13	12.2	15.2	18.2	21.2	24.2
0.85	10 3/16	....	1.59	2.39	3.12	4.67	6.22	9.30	12.4	15.5	18.5	21.6	24.6
0.86	10 5/16	....	1.62	2.44	3.18	4.76	6.33	9.48	12.6	15.8	18.9	22.0	25.1
0.87	10 7/16	....	1.65	2.48	3.24	4.84	6.44	9.65	12.8	16.0	19.2	22.4	25.6
0.88	10 9/16	....	1.68	2.52	3.29	4.93	6.56	9.82	13.1	16.3	19.6	22.8	26.1
0.89	10 11/16	....	1.71	2.57	3.35	5.01	6.68	10.0	13.3	16.6	19.9	23.2	26.5
0.90	10 13/16	....	1.74	2.61	3.41	5.10	6.80	10.2	13.6	16.9	20.3	23.7	27.0
0.91	10 15/16	....	1.77	2.66	3.46	5.19	6.92	10.4	13.8	17.2	20.7	24.1	27.5
0.92	11 1/16	....	1.81	2.70	3.52	5.28	7.03	10.5	14.0	17.5	21.0	24.5	28.0
0.93	11 3/16	....	1.84	2.75	3.58	5.37	7.15	10.7	14.3	17.8	21.4	24.9	28.5
0.94	11 1/4	....	1.87	2.79	3.64	5.46	7.27	10.9	14.5	18.1	21.8	25.4	29.0
0.95	11 3/8	....	1.90	2.84	3.70	5.55	7.39	11.1	14.8	18.4	22.1	25.8	29.5
0.96	11 1/2	....	1.93	2.88	3.76	5.64	7.51	11.3	15.0	18.8	22.5	26.2	30.0
0.97	11 5/8	....	1.97	2.93	3.82	5.73	7.63	11.4	15.3	19.1	22.9	26.7	30.5
0.98	11 3/4	....	2.00	2.98	3.88	5.82	7.75	11.6	15.5	19.4	23.2	27.1	31.0
0.99	11 7/8	....	2.03	3.02	3.94	5.91	7.88	11.8	15.8	19.7	23.6	27.6	31.5
1.00	12	....	2.06	3.07	4.00	6.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0
1.01	12 1/8	....	2.09	3.12	4.06	6.09	8.12	12.2	16.3	20.3	24.4	28.4	32.5
1.02	12 1/4	....	2.12	3.17	4.12	6.19	8.25	12.4	16.5	20.6	24.8	28.9	33.0
1.03	12 3/8	....	2.16	3.21	4.18	6.28	8.38	12.6	16.8	21.0	25.2	29.4	33.6
1.04	12 1/2	....	2.19	3.26	4.25	6.37	8.50	12.8	17.0	21.3	25.6	29.8	34.1
1.05	12 5/8	....	2.22	3.31	4.31	6.47	8.63	13.0	17.3	21.6	25.9	30.3	34.6
1.06	12 3/4	....	2.26	3.36	4.37	6.56	8.76	13.2	17.5	21.9	26.3	30.7	35.1
1.07	12 13/16	....	2.29	3.40	4.43	6.66	8.88	13.3	17.8	22.3	26.7	31.2	35.7
1.08	12 15/16	....	2.32	3.45	4.50	6.75	9.01	13.5	18.1	22.6	27.1	31.7	36.2
1.09	13 1/16	....	2.36	3.50	4.56	6.85	9.14	13.7	18.3	22.9	27.5	32.1	36.8
1.10	13 3/16	....	2.40	3.55	4.62	6.95	9.27	13.9	18.6	23.3	27.9	32.6	37.3
1.11	13 5/16	....	2.43	3.60	4.68	7.04	9.40	14.1	18.9	23.6	28.4	33.1	37.8
1.12	13 7/16	....	2.46	3.65	4.75	7.14	9.54	14.3	19.1	23.9	28.8	33.6	38.4
1.13	13 9/16	....	2.50	3.70	4.82	7.24	9.67	14.5	19.4	24.3	29.2	34.1	38.9
1.14	13 11/16	....	2.53	3.75	4.88	7.34	9.80	14.7	19.7	24.6	29.6	34.5	39.5
1.15	13 13/16	....	2.57	3.80	4.94	7.44	9.94	14.9	19.9	25.0	30.0	35.0	40.1
1.16	13 15/16	....	2.60	3.85	5.01	7.54	10.1	15.1	20.2	25.3	30.4	35.5	40.6
1.17	14 1/16	....	2.64	3.90	5.08	7.64	10.2	15.3	20.5	25.7	30.8	36.0	41.2
1.18	14 3/16	....	2.68	3.95	5.15	7.74	10.3	15.6	20.8	26.0	31.3	36.5	41.8
1.19	14 1/4	....	2.71	4.01	5.21	7.84	10.5	15.8	21.1	26.4	31.7	37.0	42.3
1.20	14 3/8	....	2.75	4.06	5.28	7.94	10.6	16.0	21.3	26.7	32.1	37.5	42.9
1.21	14 1/2	....	2.78	4.11	5.34	8.05	10.8	16.2	21.6	27.1	32.5	38.0	43.5
1.22	14 5/8	....	2.82	4.16	5.41	8.15	10.9	16.4	21.9	27.4	33.0	38.5	44.1
1.23	14 3/4	....	2.86	4.22	5.48	8.25	11.0	16.6	22.2	27.8	33.4	39.0	44.6
1.24	14 7/8	....	2.89	4.27	5.55	8.36	11.2	16.8	22.5	28.1	33.8	39.5	45.2
1.25	15	....	......	4.32	5.62	8.46	11.3	17.0	22.8	28.5	34.3	40.0	45.8
1.26	15 1/8	....	......	4.37	5.69	8.56	11.5	17.2	23.0	28.9	34.7	40.5	46.4
1.27	15 1/4	....	......	4.43	5.76	8.67	11.6	17.4	23.3	29.2	35.1	41.1	47.0
1.28	15 3/8	....	......	4.48	5.82	8.77	11.7	17.7	23.6	29.6	35.6	41.6	47.6
1.29	15 1/2	....	......	4.53	5.89	8.88	11.9	17.9	23.9	30.0	36.0	42.1	48.2
1.30	15 5/8	....	......	4.59	5.96	8.99	12.0	18.1	24.2	30.3	36.5	42.6	4.88
1.31	15 3/4	....	......	4.64	6.03	9.09	12.2	18.3	24.5	30.7	36.9	43.1	49.4
1.32	15 13/16	....	......	4.69	6.10	9.20	12.3	18.5	24.8	31.1	37.4	43.7	50.0
1.33	15 15/16	....	......	4.75	6.18	9.30	12.4	18.8	25.1	31.4	37.8	44.2	50.6
1.34	16 1/16	....	......	4.80	6.25	9.41	12.6	19.0	25.4	31.8	38.3	44.7	51.2

TABLE NO. 7—*Continued*

Upper head, Ha Feet	Inches (approx.)	3 in.	6 in.	9 in.	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
		THROAT WIDTH (Flow in cubic feet per second)											
1.35	16 3/16	......	......	4.86	6.32	9.52	12.7	19.2	25.7	32.2	38.7	45.3	51.8
1.36	16 5/16	......	......	4.92	6.39	9.63	12.9	19.4	26.0	32.6	39.2	45.8	52.5
1.37	16 7/16	......	......	4.97	6.46	9.74	13.0	19.6	26.3	33.0	39.7	46.4	53.1
1.38	16 9/16	......	......	5.03	6.53	9.85	13.2	19.9	26.6	33.3	40.1	46.9	53.7
1.39	16 11/16	......	......	5.08	6.60	9.96	13.3	20.1	26.9	33.7	40.6	47.4	54.3
1.40	16 13/16	......	......	......	6.68	10.1	13.5	20.3	27.2	34.1	41.1	48.0	55.0
1.41	16 15/16	......	......	......	6.75	10.2	13.6	20.6	27.5	34.5	41.5	48.5	55.6
1.42	17 1/16	......	......	......	6.82	10.3	13.8	20.8	27.8	34.9	42.0	49.1	56.2
1.43	17 3/16	......	......	......	6.89	10.4	13.9	21.0	28.1	35.3	42.5	49.6	56.9
1.44	17 1/4	......	......	......	6.97	10.5	14.1	21.2	28.5	35.7	42.9	50.2	57.5
1.45	17 3/8	......	......	......	7.04	10.6	14.2	21.5	28.8	36.1	43.4	50.8	58.1
1.46	17 1/2	......	......	......	7.12	10.7	14.4	21.7	29.1	36.5	43.9	51.3	58.8
1.47	17 5/8	......	......	......	7.19	10.8	14.5	21.9	29.4	36.9	44.4	51.9	59.4
1.48	17 3/4	......	......	......	7.26	11.0	14.7	22.2	29.7	37.3	44.9	52.4	60.1
1.49	17 7/8	......	......	......	7.34	11.1	14.9	22.4	30.0	37.7	45.3	53.0	60.7
1.50	18	......	......	......	7.41	11.2	15.0	22.6	30.3	38.1	45.8	53.6	61.4
1.51	18 1/8	......	......	......	7.49	11.3	15.2	22.9	30.7	38.5	46.3	54.2	62.1
1.52	18 1/4	......	......	......	7.57	11.4	15.3	23.1	31.0	38.9	46.8	54.7	62.7
1.53	18 3/8	......	......	......	7.64	11.5	15.5	23.4	31.3	39.3	47.3	55.3	63.4
1.54	18 1/2	......	......	......	7.72	11.7	15.6	23.6	31.6	39.7	47.8	55.9	64.0
1.55	18 5/8	......	......	......	7.80	11.8	15.8	23.8	32.0	40.1	48.3	56.5	64.7
1.56	18 3/4	......	......	......	7.87	11.9	15.9	24.1	32.3	40.5	48.8	57.1	65.4
1.57	18 13/16	......	......	......	7.95	12.0	16.1	24.3	32.6	40.9	49.3	57.7	66.1
1.58	18 15/16	......	......	......	8.02	12.1	16.3	24.6	32.9	41.4	49.8	58.2	66.7
1.59	19 1/16	......	......	......	8.10	12.2	16.4	24.8	33.3	41.8	50.3	58.8	67.4
1.60	19 3/16	......	......	......	8.18	12.4	16.6	25.1	33.6	42.2	50.8	59.4	68.1
1.61	19 5/16	......	......	......	8.26	12.5	16.7	25.3	33.9	42.6	51.3	60.0	68.8
1.62	19 7/16	......	......	......	8.34	12.6	16.9	25.5	34.3	43.0	51.8	60.6	69.5
1.63	19 9/16	......	......	......	8.42	12.7	17.1	25.8	34.6	43.4	52.3	61.2	70.2
1.64	19 11/16	......	......	......	8.49	12.8	17.2	26.0	34.9	43.9	52.8	61.8	70.9
1.65	19 13/16	......	......	......	8.57	13.0	17.4	26.3	35.3	44.3	53.3	62.4	71.6
1.66	19 15/16	......	......	......	8.65	13.1	17.6	26.5	35.6	44.7	53.9	63.0	72.3
1.67	20 1/16	......	......	......	8.73	13.2	17.7	26.8	35.9	45.1	54.4	63.6	73.0
1.68	20 3/16	......	......	......	8.81	13.3	17.9	27.0	36.3	45.6	54.9	64.3	73.7
1.69	20 1/4	......	......	......	8.89	13.5	18.0	27.3	36.6	46.0	55.4	64.9	74.4
1.70	20 3/8	......	......	......	8.97	13.6	18.2	27.6	37.0	46.4	56.0	65.5	75.1
1.71	20 1/2	......	......	......	9.05	13.7	18.4	27.8	37.3	46.9	56.5	66.1	75.8
1.72	20 5/8	......	......	......	9.13	13.8	18.5	28.1	37.7	47.3	57.0	66.7	76.5
1.73	20 3/4	......	......	......	9.21	13.9	18.7	28.3	38.0	47.7	57.5	67.3	77.2
1.74	20 7/8	......	......	......	9.29	14.1	18.9	28.6	38.3	48.2	58.1	68.0	77.9
1.75	21	......	......	......	9.38	14.2	19.0	28.8	38.7	48.6	58.6	68.6	78.7
1.76	21 1/8	......	......	......	9.46	14.3	19.2	29.1	39.0	49.1	59.1	69.2	79.4
1.77	21 1/4	......	......	......	9.54	14.4	19.4	29.3	39.4	49.5	59.7	69.9	80.1
1.78	21 3/8	......	......	......	9.62	14.6	19.6	29.6	39.7	49.9	60.2	70.5	80.8
1.79	21 1/2	......	......	......	9.70	14.7	19.7	29.9	40.1	50.4	60.7	71.1	81.6
1.80	21 5/8	......	......	......	9.79	14.8	19.9	30.1	40.5	50.8	61.3	71.8	82.3
1.81	21 3/4	......	......	......	9.87	15.0	20.1	30.4	40.8	51.3	61.8	72.4	83.0
1.82	21 13/16	......	......	......	9.95	15.1	20.2	30.7	41.2	51.7	62.4	73.0	83.8
1.83	21 15/16	......	......	......	10.0	15.2	20.4	30.9	41.5	52.2	62.9	73.7	84.5
1.84	22 1/16	......	......	......	10.1	15.3	20.6	31.2	41.9	52.6	63.5	74.3	85.3
1.85	22 3/16	......	......	......	10.2	15.5	20.8	31.5	42.2	53.1	64.0	75.0	86.0
1.86	22 5/16	......	......	......	10.3	15.6	20.9	31.7	42.6	53.6	64.6	75.6	86.8
1.87	22 7/16	......	......	......	10.4	15.7	21.1	32.0	43.0	54.0	65.1	76.3	87.5
1.88	22 9/16	......	......	......	10.5	15.8	21.3	32.3	43.3	54.5	65.7	76.9	88.3
1.89	22 11/16	......	......	......	10.5	16.0	21.5	32.5	43.7	54.9	66.3	77.6	89.0
1.90	22 13/16	......	......	......	10.6	16.1	21.6	32.8	44.1	55.4	66.8	78.2	89.8
1.91	22 15/16	......	......	......	10.7	16.2	21.8	33.1	44.4	55.9	67.4	78.9	90.5
1.92	23 1/16	......	......	......	10.8	16.4	22.0	33.3	44.8	56.3	67.9	79.6	91.3
1.93	23 3/16	......	......	......	10.9	16.5	22.2	33.6	45.2	56.8	68.5	80.2	92.1
1.94	23 1/4	......	......	......	11.0	16.6	22.4	33.9	45.5	57.3	69.1	80.9	92.8
1.95	23 3/8	......	......	......	11.1	16.7	22.5	34.1	45.9	57.7	69.6	81.6	93.6
1.96	23 1/2	......	......	......	11.1	16.9	22.7	34.4	46.3	58.2	70.2	82.2	94.4
1.97	23 5/8	......	......	......	11.2	17.0	22.9	34.7	46.6	58.7	70.8	82.9	95.1
1.98	23 3/4	......	......	......	11.3	17.2	23.1	35.0	47.0	59.1	71.4	83.6	95.9
1.99	23 7/8	......	......	......	11.4	17.3	23.2	35.3	47.4	59.6	71.9	84.3	96.7

TABLE NO. 7—*Continued*

Upper head, Ha Feet	Inches (approx.)	3 in.	6 in.	9 in.	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
		THROAT WIDTH (Flow in cubic feet per second)											
2.00	24	......	......	......	11.5	17.4	23.4	35.5	47.8	60.1	72.5	84.9	97.5
2.01	24 1/8	......	......	......	11.6	17.6	23.6	35.8	48.1	60.6	73.1	85.6	98.3
2.02	24 1/4	......	......	......	11.7	17.7	23.8	36.1	48.5	61.0	73.7	86.3	99.1
2.03	24 3/8	......	......	......	11.8	17.8	24.0	36.4	48.9	61.5	74.2	87.0	99.8
2.04	24 1/2	......	......	......	11.8	18.0	24.2	36.7	49.3	62.0	74.8	87.7	100.6
2.05	24 5/8	......	......	......	11.9	18.1	24.3	36.9	49.7	62.5	75.4	88.4	101.4
2.06	24 3/4	......	......	......	12.0	18.2	24.5	37.2	50.1	63.0	76.0	89.1	102.2
2.07	24 13/16	......	......	......	12.1	18.4	24.7	37.5	50.4	63.5	76.6	89.8	103.0
2.08	24 15/16	......	......	......	12.2	18.5	24.9	37.8	50.8	63.9	77.2	90.4	103.8
2.09	25 1/16	......	......	......	12.3	18.7	25.1	38.1	51.2	64.4	77.8	91.1	104.6
2.10	25 3/16	......	......	......	12.4	18.8	25.3	38.4	51.6	64.9	78.4	91.8	105.4
2.11	25 5/16	......	......	......	12.5	18.9	25.5	38.6	52.0	65.4	79.0	92.5	106.2
2.12	25 7/16	......	......	......	12.6	19.0	25.6	38.9	52.4	65.9	79.6	93.3	107.0
2.13	25 9/16	......	......	......	12.6	19.2	25.8	39.2	52.8	66.4	80.2	94.0	107.9
2.14	25 11/16	......	......	......	12.7	19.3	26.0	39.5	53.2	66.9	80.8	94.7	108.7
2.15	25 13/16	......	......	......	12.8	19.5	26.2	39.8	53.5	67.4	81.4	95.4	109.5
2.16	25 15/16	......	......	......	12.9	19.6	26.4	40.1	53.9	67.9	82.0	96.1	110.3
2.17	26 1/16	......	......	......	13.0	19.7	26.6	40.4	54.3	68.4	82.6	96.8	111.1
2.18	26 3/16	......	......	......	13.1	19.9	26.8	40.7	54.7	68.9	83.2	97.5	111.9
2.19	26 1/4	......	......	......	13.2	20.0	27.0	41.0	55.1	69.4	83.8	98.2	112.8
2.20	26 3/8	......	......	......	13.3	20.2	27.2	41.3	55.5	69.9	84.4	98.9	113.6
2.21	26 1/2	......	......	......	13.4	20.3	27.3	41.5	55.9	70.4	85.0	99.7	114.4
2.22	26 5/8	......	......	......	13.5	20.5	27.5	41.8	56.3	70.9	85.6	100.4	115.3
2.23	26 3/4	......	......	......	13.6	20.6	27.7	42.1	56.7	71.4	86.3	101.1	116.1
2.24	26 7/8	......	......	......	13.7	20.7	27.9	42.4	57.1	71.9	86.9	101.8	116.9
2.25	27	......	......	......	13.7	20.9	28.1	42.7	57.5	72.4	87.5	102.6	117.8
2.26	27 1/8	......	......	......	13.8	21.0	28.3	43.0	57.9	72.9	88.1	103.3	118.6
2.27	27 1/4	......	......	......	13.9	21.2	28.5	43.3	58.3	73.5	88.7	104.0	119.5
2.28	27 3/8	......	......	......	14.0	21.3	28.7	43.6	58.7	74.0	89.4	104.8	120.3
2.29	27 1/2	......	......	......	14.1	21.4	28.9	43.9	59.2	74.5	90.0	105.5	121.2
2.30	27 5/8	......	......	......	14.2	21.6	29.1	44.2	59.6	75.0	90.6	106.2	122.0
2.31	27 3/4	......	......	......	14.3	21.7	29.3	44.5	60.0	75.5	91.2	107.0	122.9
2.32	27 13/16	......	......	......	14.4	21.9	29.5	44.8	60.4	76.0	91.9	107.7	123.7
2.33	27 15/16	......	......	......	14.5	22.0	29.7	45.1	60.8	76.6	92.5	108.5	124.6
2.34	28 1/16	......	......	......	14.6	22.2	29.9	45.4	61.2	77.1	93.1	109.2	125.4
2.35	28 3/16	......	......	......	14.7	22.4	30.1	45.7	61.6	77.6	93.8	110.0	126.3
2.36	28 5/16	......	......	......	14.8	22.5	30.3	46.0	62.0	78.1	94.4	110.7	127.2
2.37	28 7/16	......	......	......	14.9	22.6	30.5	46.4	62.4	78.7	95.1	111.5	128.0
2.38	28 9/16	......	......	......	15.0	22.8	30.7	46.7	62.9	79.2	95.7	112.2	128.9
2.39	28 11/16	......	......	......	15.1	22.9	30.9	47.0	63.3	79.7	96.3	113.0	129.8
2.40	28 13/16	......	......	......	15.2	23.0	31.1	47.3	63.7	80.3	97.0	113.7	130.7
2.41	28 15/16	......	......	......	15.3	23.2	31.3	47.6	64.1	80.8	97.6	114.5	131.5
2.42	29 1/16	......	......	......	15.4	23.3	31.5	47.9	64.5	81.3	98.3	115.3	132.4
2.43	29 3/16	......	......	......	15.5	23.5	31.7	48.2	65.0	81.8	98.9	116.0	133.3
2.44	29 1/4	......	......	......	15.6	23.7	31.9	48.5	65.4	82.4	99.6	116.8	134.2
2.45	29 3/8	......	......	......	15.6	23.8	32.1	48.8	65.8	82.9	100.2	117.6	135.1
2.46	29 1/2	......	......	......	15.7	23.9	32.3	49.1	66.2	83.5	100.9	118.3	135.9
2.47	29 5/8	......	......	......	15.9	24.1	32.5	49.5	66.7	84.0	101.5	119.1	136.8
2.48	29 3/4	......	......	......	15.9	24.2	32.7	49.8	67.1	84.5	102.2	119.9	137.7
2.49	29 7/8	......	......	......	16.0	24.4	32.9	50.1	67.5	85.1	102.8	120.6	138.6
2.50	30	......	......	......	16.1	24.6	33.1	50.4	67.9	85.6	103.5	121.4	139.5

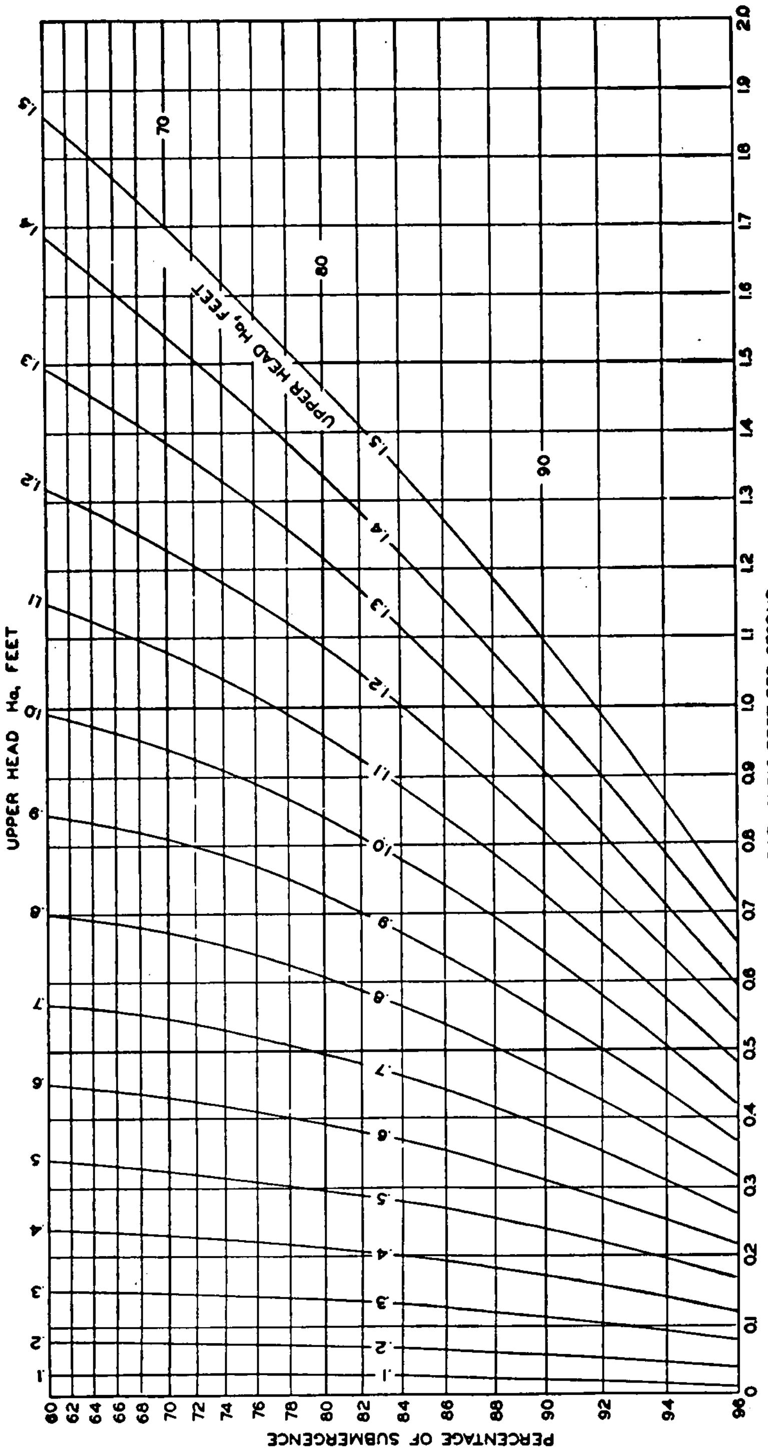


FIGURE 1.—Diagram showing the rate of submerged flow, in cubic feet per second, through a 3-inch Parshall measuring flume.

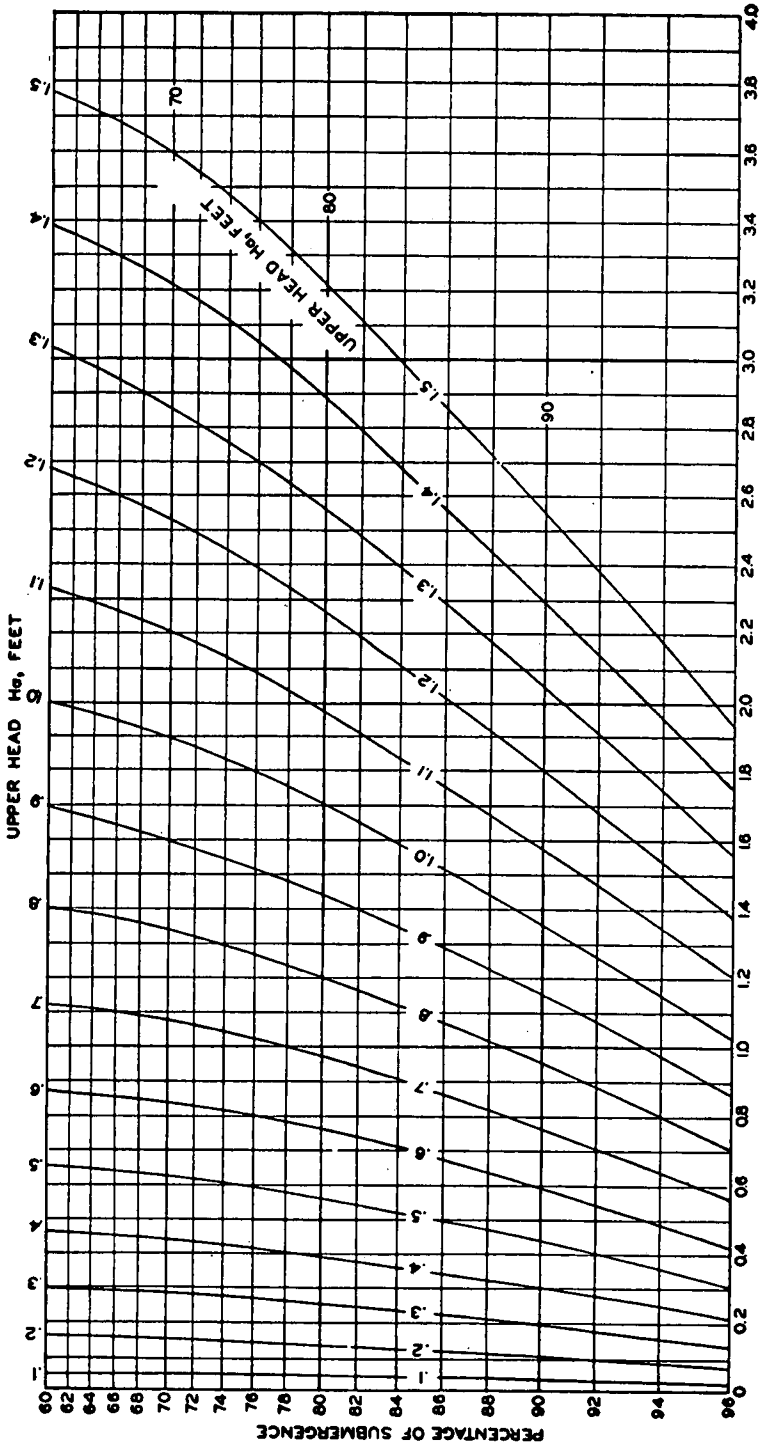


FIGURE 2.—Diagram showing the rate of submerged flow, in cubic feet per second, through a 6-inch Parshall measuring flume.

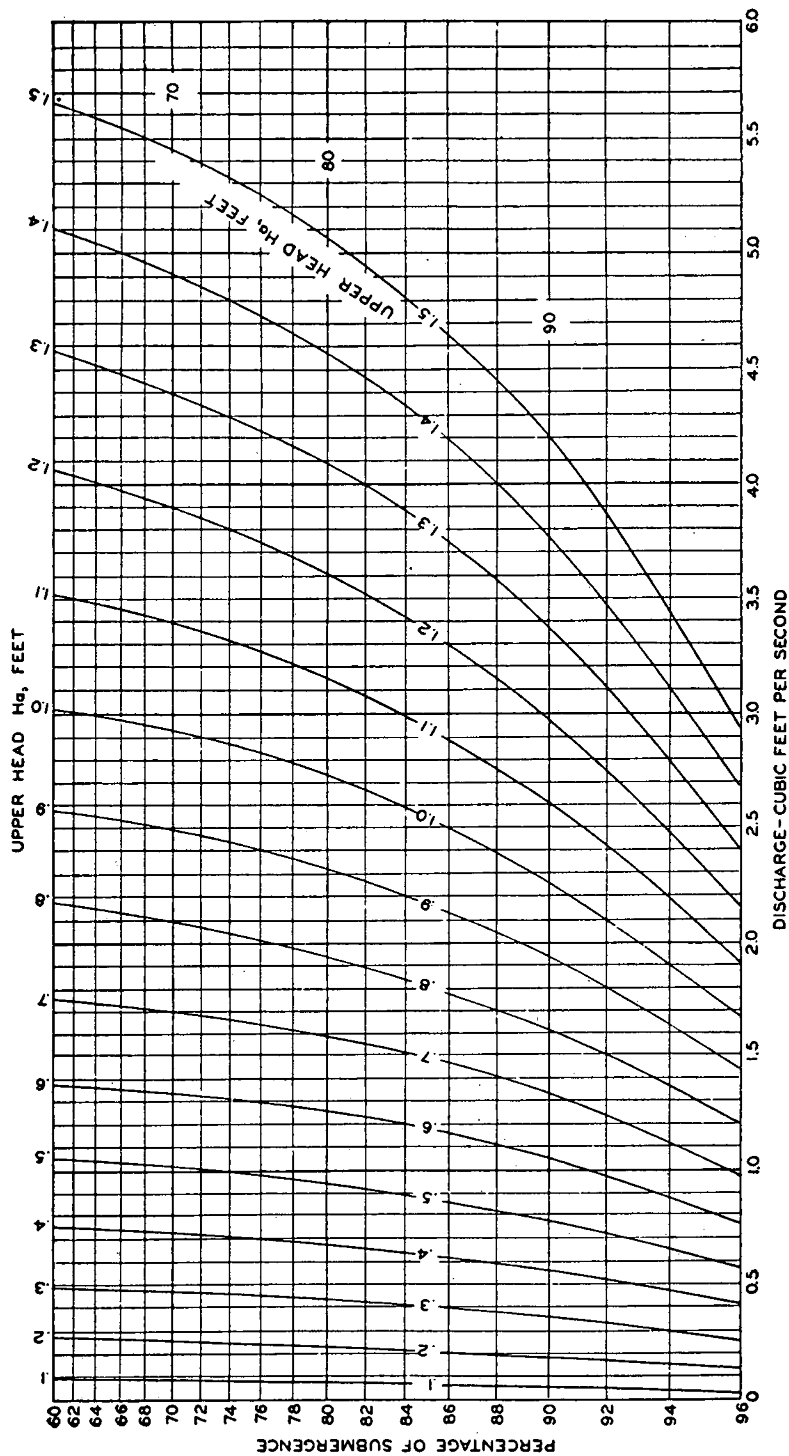


FIGURE 3.—Diagram showing the rate of submerged flow, in cubic feet per second, through a 9-inch Parshall measuring flume.

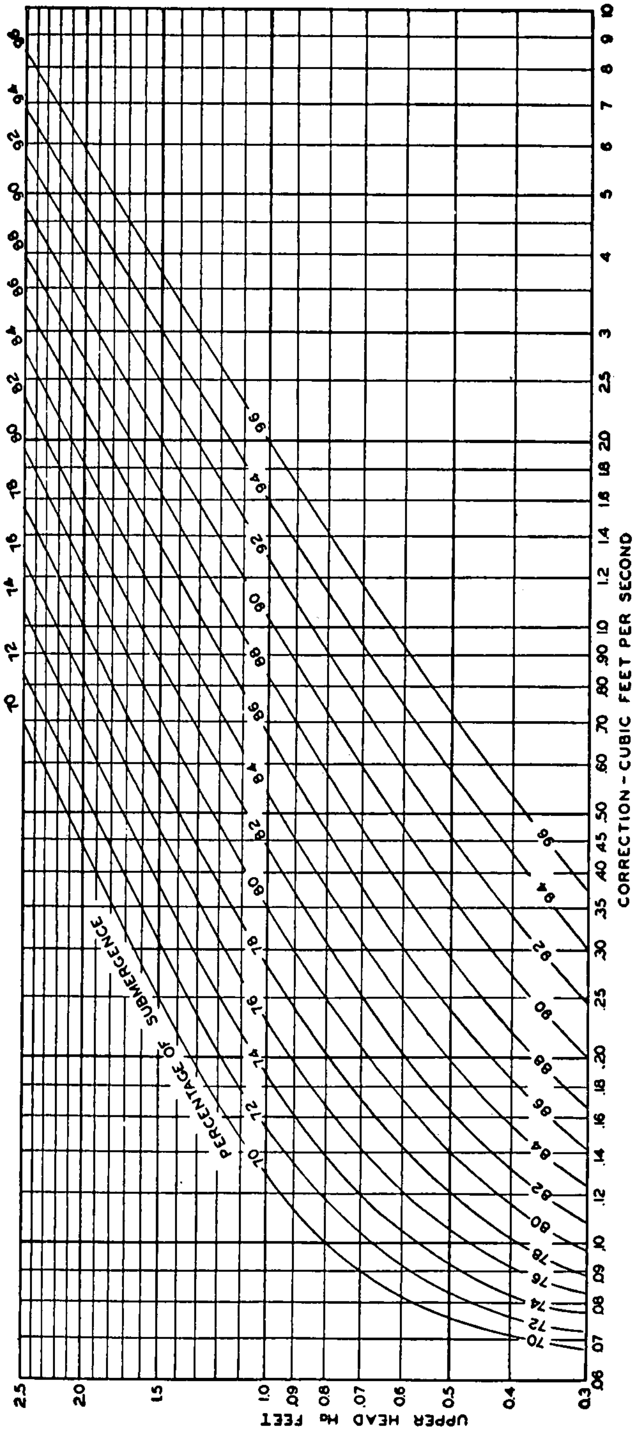


FIGURE 4.—Diagram for computing the rate of submerged flow, in cubic feet per second, through a 1-foot Parshall measuring flume.

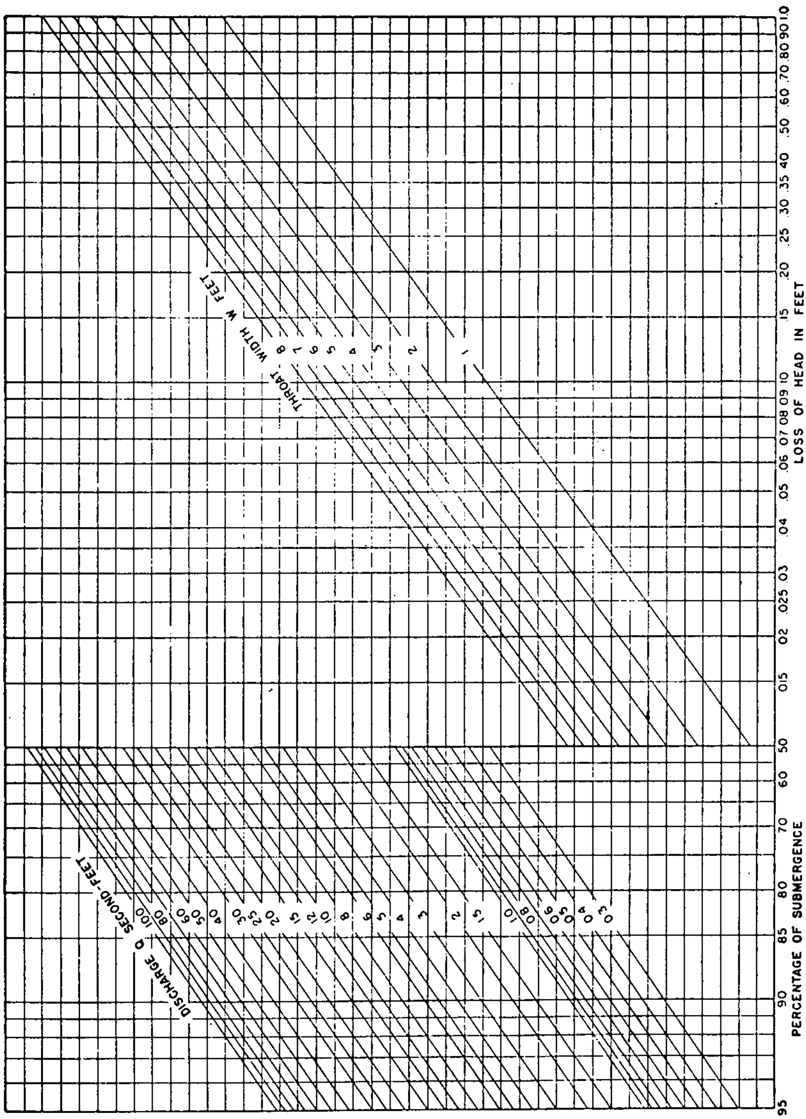


FIGURE 5.—Diagram for determining the loss of head through the Parshall flume, 1–8-foot sizes.

TABLE 8
Coefficients for Pipe of Circular Section Flowing Partly Full

[Coefficients for (1) area, (2) wetted perimeter, (3) hydraulic radius, (4) conveyance, (5) discharge for critical-depth flow, and (6) top width]

d/D [1]	(1) $A=C_aD^2$ C_a	(2) $P=C_pD$ C_p	(3) $R=C_rD$ C_r	(4) $K=C_k\frac{D^{8/3}}{n}$ C_k	(5) $Q=C_qD^{5/2}$ C_q	(6) $T=C_tD$ C_t	d/D [1]	(1) $A=C_aD^2$ C_a	(2) $P=C_pD$ C_p	(3) $R=C_rD$ C_r	(4) $K=C_k\frac{D^{8/3}}{n}$ C_k	(5) $Q=C_qD^{5/2}$ C_q	(6) $T=C_tD$ C_t
0.01	0.0013	0.2003	0.0066	0.000068	0.0006	0.199	0.51	0.4027	1.5908	0.2531	0.2394	1.449	1.000
.02	.0037	.2838	.0132	.000307	.0025	.280	.52	.4127	1.6108	.2562	.2472	1.504	.999
.03	.0069	.3482	.0197	.000747	.0055	.341	.53	.4227	1.6308	.2592	.2556	1.560	.998
.04	.0105	.4027	.0262	.001376	.0098	.392	.54	.4327	1.6509	.2621	.2630	1.616	.997
.05	.0147	.4510	.0325	.002228	.0153	.436	.55	.4426	1.6710	.2649	.2710	1.674	.995
.06	.0192	.4949	.0389	.00328	.0220	.475	.56	.4526	1.6911	.2676	.2791	1.733	.993
.07	.0242	.5355	.0451	.00457	.0298	.510	.57	.4625	1.7113	.2703	.2873	1.792	.990
.08	.0294	.5735	.0513	.00601	.0389	.543	.58	.4724	1.7315	.2728	.2955	1.853	.987
.09	.0350	.6094	.0575	.00775	.0491	.572	.59	.4822	1.7518	.2753	.3031	1.915	.984
.10	.0409	.6435	.0635	.00966	.0605	.600	.60	.4920	1.7722	.2776	.3115	1.977	.980
.11	.0470	.6761	.0695	.0118	.0731	.626	.61	.5018	1.7926	.2799	.3192	2.041	.975
.12	.0534	.7075	.0755	.0142	.0868	.650	.62	.5115	1.8132	.2821	.3268	2.106	.971
.13	.0600	.7377	.0813	.0168	.1016	.673	.63	.5212	1.8338	.2842	.3346	2.172	.966
.14	.0668	.7670	.0871	.0195	.1176	.694	.64	.5308	1.8546	.2862	.3423	2.239	.960
.15	.0739	.7954	.0929	.0225	.1347	.714	.65	.5404	1.8755	.2882	.3501	2.307	.954
.16	.0811	.8230	.0985	.0257	.1530	.733	.66	.5499	1.8965	.2900	.3579	2.376	.947
.17	.0885	.8500	.1042	.0291	.1724	.751	.67	.5594	1.9177	.2917	.3658	2.446	.940
.18	.0961	.8763	.1097	.0327	.1928	.768	.68	.5687	1.9391	.2933	.3727	2.518	.933
.19	.1039	.9020	.1152	.0366	.2144	.785	.69	.5780	1.9606	.2948	.3805	2.591	.925
.20	.1118	.9273	.1206	.0405	.2371	.800	.70	.5872	1.9823	.2962	.3874	2.666	.917
.21	.1199	.9521	.1259	.0446	.2609	.815	.71	.5964	2.0042	.2975	.3953	2.741	.908
.22	.1281	.9764	.1312	.0491	.2857	.828	.72	.6054	2.0264	.2987	.4021	2.819	.898
.23	.1365	1.0003	.1364	.0537	.3116	.842	.73	.6143	2.0488	.2998	.4090	2.898	.888
.24	.1449	1.0239	.1416	.0586	.3386	.854	.74	.6231	2.0714	.3008	.4157	2.978	.877
.25	.1535	1.0472	.1466	.0634	.3666	.866	.75	.6319	2.0944	.3017	.4226	3.061	.866
.26	.1623	1.0701	.1516	.0685	.3957	.877	.76	.6405	2.1176	.3024	.4283	3.145	.854
.27	.1711	1.0928	.1566	.0740	.4259	.888	.77	.6489	2.1412	.3031	.4349	3.231	.842
.28	.1800	1.1152	.1614	.0792	.4571	.898	.78	.6573	2.1652	.3036	.4415	3.320	.828
.29	.1890	1.1373	.1662	.0848	.4893	.908	.79	.6655	2.1895	.3039	.4470	3.411	.815
.30	.1982	1.1593	.1709	.0907	.523	.917	.80	.6736	2.2143	.3042	.4524	3.505	.800
.31	.2074	1.1810	.1756	.0968	.557	.925	.81	.6815	2.2395	.3043	.4578	3.602	.785
.32	.2167	1.2025	.1802	.1027	.592	.933	.82	.6893	2.2653	.3043	.4630	3.702	.768
.33	.2260	1.2239	.1847	.1088	.628	.940	.83	.6969	2.2916	.3041	.4681	3.806	.751
.34	.2355	1.2451	.1891	.1155	.666	.947	.84	.7043	2.3186	.3038	.4731	3.914	.733
.35	.2450	1.2661	.1935	.1220	.704	.954	.85	.7115	2.3462	.3033	.4768	4.028	.714
.36	.2546	1.2870	.1978	.1283	.743	.960	.86	.7186	2.3746	.3026	.4816	4.147	.694
.37	.2642	1.3078	.2020	.1350	.784	.966	.87	.7254	2.4038	.3018	.4851	4.272	.673
.38	.2739	1.3284	.2062	.1421	.825	.971	.88	.7320	2.4341	.3007	.4884	4.406	.650
.39	.2836	1.3490	.2102	.1488	.867	.975	.89	.7384	2.4655	.2995	.4916	4.549	.626
.40	.2934	1.3694	.2142	.1561	.910	.980	.90	.7445	2.4981	.2980	.4935	4.70	.600
.41	.3032	1.3898	.2182	.1631	.955	.984	.91	.7504	2.5322	.2963	.4951	4.87	.572
.42	.3130	1.4101	.2220	.1702	1.000	.987	.92	.7560	2.5681	.2944	.4966	5.06	.543
.43	.3229	1.4303	.2258	.1780	1.046	.990	.93	.7612	2.6061	.2921	.4977	5.27	.510
.44	.3328	1.4505	.2295	.1854	1.093	.993	.94	.7662	2.6467	.2895	.4979	5.52	.475
.45	.3428	1.4706	.2331	.1931	1.141	.995	.95	.7707	2.6906	.2865	.4970	5.81	.436
.46	.3527	1.4907	.2366	.2002	1.190	.997	.96	.7749	2.7389	.2829	.4963	6.18	.392
.47	.3627	1.5108	.2401	.2080	1.240	.998	.97	.7785	2.7934	.2787	.4940	6.67	.341
.48	.3727	1.5308	.2435	.2160	1.291	.999	.98	.7817	2.8578	.2735	.4902	7.41	.280
.49	.3827	1.5508	.2468	.2235	1.343	1.000	.99	.7841	2.9412	.2666	.4824	8.83	.199
.50	.3927	1.5708	.2500	.2317	1.396	1.000	1.00	.7854	3.1416	.2500	.4633	-------	.000

D=diameter of pipe (ft.).
d=depth of water (ft.)

Find $\frac{d}{D}$

Use table column 1 (ca)$=\frac{\text{Area}}{D^2}$

$\frac{\text{Area}}{D^2}\times D^2=$ total area (ft^2)

Measure velocity with current meter
Then plug into Q=AV