MEASURING WATER

IN IRRIGATION CHANNELS WITH PARSHALL FLUMES AND SMALL WEIRS

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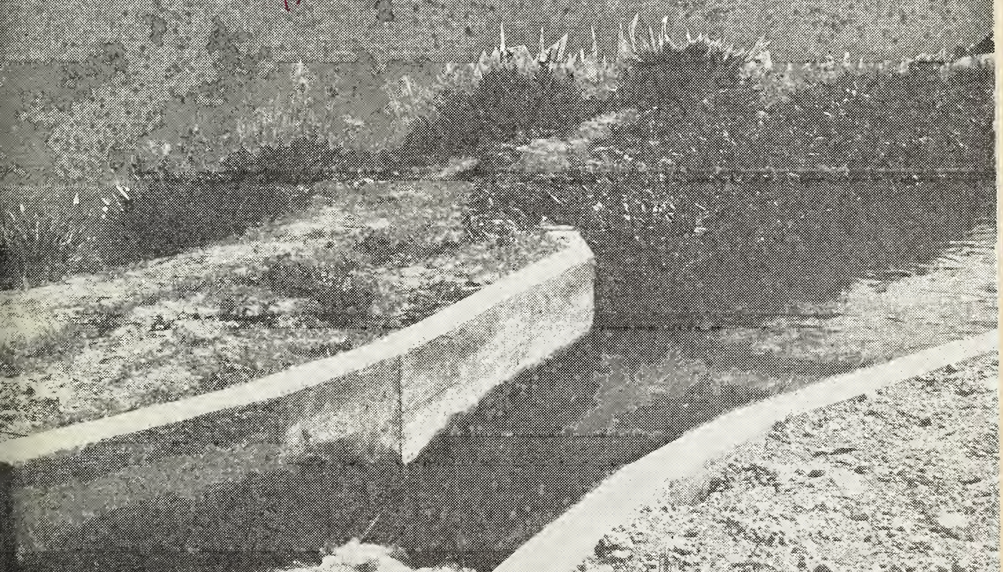

Soil Conservation Service CIRCULAR NO. 84
UNITED STATES DEPARTMENT OF AGRICULTUR

The principal use of weirs and small Parshall measuring flumes, as described in this circular, is that of measuring irrigation water as it is delivered to farmers from main canals and ditches.

Throughout the Western States most major water supplies are now fully appropriated. Accurate means of measuring water into the canals and ditches and assuring delivery of the proper amounts according to the rights or shares owned in the common ditch supplies are therefore needed.

This circular describes practical measuring devices for the beneficial and economical use of irrigation supplies. Standard weirs of various types and sizes are discussed. Their advantages and disadvantages, and recommendations for their use are set out. The merits of the Parshall measuring flume are also explained. This device has been perfected in sizes ranging from throat widths of 3 inches, which can accurately measure flows of 0.1 second-foot as a minimum, to that of structures having throat widths of 40 feet with a maximum capacity of more than 2,000 second-feet. Flumes as here described range in size from 3 inches to 8 feet and are limited in capacity to about 100 second-feet.

The Parshall flume is a device which performs accurately within the requirements of general irrigation practice. One decided advantage is its ability to withstand a relatively high degree of submergence without retarding the free-flow rate of discharge. High velocity of flow through the structure eliminates deposits of sand or silt on the floor of the flume, which, if permitted to accumulate, would affect the accuracy of measurement. It can be operated under submergence to the point where a small loss in head may occur. Care must be taken in fixing properly the elevation of the crest of the flume when placed in a channel of flat grade. For free-flow measurement only a single head need be observed. For submerged flow two heads must be determined and a simple calculation made to compute the rate of discharge.

The measuring flumes described may be built of wood, concrete, or sheet metal. The casting of monolithic reinforced concrete Parshall measuring flumes of small sizes, intended for farm deliveries, is also fully discussed.

This circular supersedes Farmers' Bulletin 1683, Measuring Water in Irrigation Channels.

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UNITED STATES DEPARTMENT OF AGRICULTURE

Measuring Water in Irrigation Channels With Parshall Flumes and Small Weirs[1]

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CONTENTS

INTRODUCTION

The principal objectives of measuring irrigation water flowing in main canals and laterals, and as it is delivered to farmers, are its proper distribution and its beneficial but economical use. This bulletin describes several practical water-measuring devices suitable for use in open irrigation channels, principally as adapted to relatively small flows in laterals and turn-out deliveries to individual water users. It describes the most economical methods of constructing reinforced concrete Parshall flumes for measuring moderate flows by the use of portable forms.

WEIRS

The weir is the simplest of the practical devices used in the measurement of small water supplies. When properly constructed and operated under standard controlled conditions it is the most accurate. In its simplest form, it consists of a bulkhead of timber or concrete across the channel, having in its top edge a notched opening of fixed dimensions and shape through which a stream may flow. This opening is called the weir notch; its bottom edge is the crest; and the depth of water passing over the crest is the head (as measured at a definite point upstream from the weir bulkhead). The horizontal distances from the ends of the crest to the side walls of the weir box are called the end

[1] Prepared under the direction of George D. Clyde, Chief, Division of Irrigation and Water Conservation, Soil Conservation Service Research, and in cooperation with the Colorado Agricultural Experiment Station.

contractions; and the vertical distance from the crest to the floor of the weir box or the bed of the channel is the bottom contraction.

When these distances are great enough to cause water to pond above the weir, so that it approaches the weir notch at a low velocity, the weir is said to have complete contractions. To bring about this condition, the banks or sides of the channel upstream from the bulkhead must stand from the ends of the crest a distance of at least twice the maximum depth of water over the weir; the bottom or bed of the channel must be lower than the crest by at least three times this maximum depth, and the velocity of approach must not exceed about 0.3 foot per second.

These limiting contraction distances so define the dimensions of the channel that a high degree of accuracy of the discharge measurements may be attained. However, since this bulletin is intended to describe measuring devices for general field use, where a reasonable degree of accuracy is acceptable, these contraction distances have been modified somewhat to conform to practical dimensions of the weir-box structure. No great sacrifice of accuracy in the measurements of flow results from this modification.

For proper operation of completely contracted weirs, the channel upstream from the bulkhead must be large enough to insure adequate stilling of the water. This stilling basin above the weir is called the weir pond. The sheet of water passing through the notch and falling over the weir crest is termed the nappe. When the water surface downstream from the bulkhead is far enough below the crest so that air moves freely beneath the nappe, the flow is said to be free; otherwise it is submerged. Observations show that a head of 0.1 foot over such weirs is enough to permit the stream to clear the downstream edges of the crest and sides.

Three types of weirs operating with complete contraction are considered in this bulletin: (1) The rectangular weir, the weir notch of which has a level crest and vertical sides; (2) the Cipolletti, or trapezoidal weir, having a level crest and the sides of the notch inclined outward from the vertical at slopes of 1 unit horizontal to 4 units vertical; (3) the 90° triangular-notch weir, formed by the sides sloping 45° from the vertical, meeting in a point. This type has no crest length.

Construction and Setting

The crest and sides of these types of weirs should be straight and sharp-edged and usually one-eighth to one-fourth inch in thickness. The crest of the rectangular and the Cipolletti weirs should be level between the end points, and the sides should be set at exactly the proper angle with the crest. The sides of the triangular-notch weir should make 45° angles with a vertical line through the point of intersection of the two sidepieces.

As a temporary expedient in making approximate measurements of small flows in earthen channels, a portable weir may be used. Such a device may be made from a piece of stiff sheet metal cut in a semicircular form approximating the shape of the cross section of the channel but somewhat larger, with a weir notch cut in the top edge. In setting such a weir, it is only necessary to force the metal plate firmly into the soft bottom and sides of the channel, at right angles to the direction of flow, and then adjust the crest to a level position by tapping down the higher side.

If a more permanent structure is desired, a wooden bulkhead supported properly by end posts set well into the sides and bottom of the ditch may be built across the channel. The weir notch may then be cut into the top of the barrier, or the top pieces of planking may be made of such length and so fixed in place as to define the sides of the notch for a particular length of crest. Experience has indicated that where the notch is made with crest and sides of wood, the edges may crack or be crushed, causing irregularities and unsatisfactory measurements. Therefore, it is the better practice to make the rectangular notch opening 3 inches longer than necessary and to use 1½- by 1½- by ⅛-inch angle-iron pieces cut to the proper length for the finished crest and sides. The sidepieces for such a rectangular weir should first be set temporarily and the crest piece leveled carefully and fixed firmly between them. A carpenter's square and level should be used in finally determining the proper position of the vertical sidepieces. Heavy round-headed screws should be used to hold the pieces firmly in place. The inside faces of the angle-iron pieces should be set flush with the edge of the planking.

It is somewhat more difficult to construct the Cipolletti type of weir if angle irons are used for the crest and sides, because of the sloping sidepieces. For this reason, it is perhaps best to cut the notch to exact dimensions in a sheet of stiff metal (16-gage galvanized iron) and then fasten the sheet to the upstream face of the bulkhead. However, the notch in the bulkhead is cut 2 inches oversize in order not to interfere with the nappe. One objection to the Cipolletti type of weir, if only a bulkhead is constructed, is the difficulty of maintaining the proper side and bottom contraction distance. (This is true also of rectangular weirs). In order to overcome the difficulty of maintaining the proper side and bottom contraction distances, the weir bulkhead may be built inside a wooden or concrete structure, such as that shown in figure 1. Dimensions of a structure suitable for these types

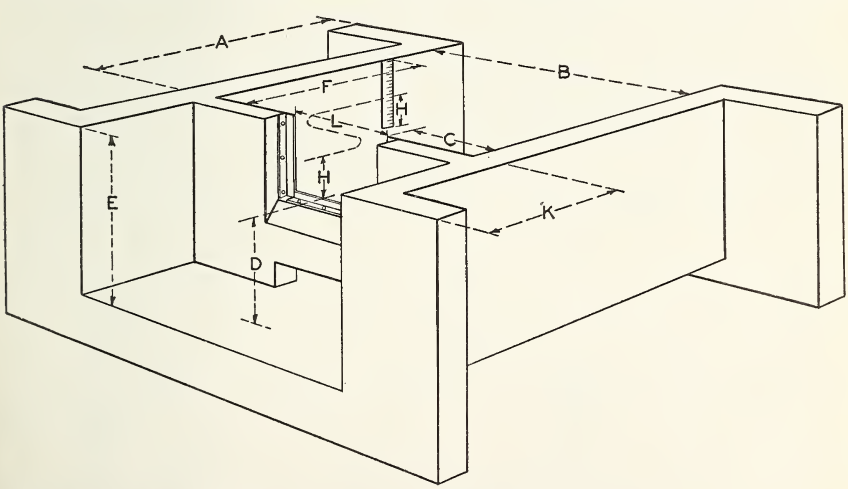

FIGURE 1.—Concrete weir box with rectangular weir notch formed by angle-iron crest and sides. Lettered dimensions are as follows: *A*, Length of box above weir notch; *B*, total width of box; *C*, end of crest to side of box; *D*, crest to bottom of box; *E*, total depth of box; *F*, gage distance; *H*, maximum head; *K*, length of box below weir notch; *L*, length of weir crest.

Table 1.—*Weir-box dimensions for rectangular, Cipolletti, and 90° triangular-notch weirs*

[Letters refer to dimensions, fig. 1]

Rectangular and Cipolletti Weirs

Approximate limits of discharge (second-feet)	*H* Maximum head	*L* Length of weir crest	*A* Length of box above weir crest	*K* Length of box below weir crest	*B* Total width of box	*E*[1] Total depth of box	*C* Distance from end of crest to side of box	*D* Distance from crest to bottom of box	*F* Gage distance
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1/10 to 3	1	1	6	2	4	3	1½	1½	4
1/5 to 6	1¼	1½	7	3	5	3¼	1¾	1½	4½
¼ to 8	1¼	2	8	4	6	3½	2	1¾	5
⅓ to 17	1½	3	9	5	7	4	2	2	5½
½ to 23	1½	4	10	6	9	4	2½	2	6
¾ to 35	1½	6	12	6	11½	4½	2¾	2½	6
1 to 50	1½	8	16	8	14	4¾	3	2¾	8
1 to 60	1½	10	20	8	17	5	3½	3	8
90° Triangular-Notch Weir									
1/10 to 2½	1	----	6	2	5	3	----	1½	4
1/10 to 4⅓	1¼	----	6½	3	6½	3¼	----	1½	5

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

of weirs are given in table 1. The letters at the heads of the columns in this table refer to the corresponding lettered dimensions in figure 1.

The weir-box structure should be set in a straight section of the channel, with the floor level in both directions and the side walls vertical. To prevent undermining or washing around the structure, cutoff walls should be provided at both ends and the backfill well tamped in place. It is desirable to set the bulkhead upstream from the lower end in order to have a portion of the floor to serve as an apron in preventing erosion of the bottom of the channel. The banks and bottom of the channel for a distance of 15 to 20 feet upstream from the weir box should be trimmed to conform approximately to the cross section of the box.

A main obstacle to accuracy in the use of weirs in the field is accumulation of sand and silt in the weir box. Cleaning by means of a hand shovel or by team and scraper where convenient is frequently necessary to maintain proper contraction distances. For cleaning the weir box an opening, large enough for deposits to be sluiced through and passed downstream, can be provided in the bulkhead at the floor line beneath the weir notch (fig.1). A removable gate or short piece of planking placed on the upstream side of the opening serves as a cover, which may be securely fixed in place when the weir is in operation.

Measurements

The rate of flow in cubic feet per second (second-feet) over the weir crest is determined directly by the depth or head (*H*) in feet and the length of crest (*L*) in feet. As the water passes through the weir notch, its surface curves downward. This curved surface, or draw-down, extends upstream a short distance from the plane of the weir notch and depends upon the depth of water over the crest. The true head (*H*) should, therefore, be determined at a point in the quiet water far enough upstream from the weir to be beyond the effect of this draw-down. In general practice, this distance to the gage point should not be less than four times the maximum head to be run over the crest. For lesser flows the same gage point should be used. Under ordinary conditions, this head may also be taken at the wall of the weir box at either end of the bulkhead. A vertical staff gage, graduated in feet, tenths, and hundredths, set with the zero mark at the elevation of the weir crest may be attached to the inside of the weir box, as shown in figure 1, upon which the true head may be observed directly. For more accurate readings of the head, use may be made of a stilling well described on page 58.

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

To determine the rate of discharge over the weir, observe the depth of water on the weir crest in feet or inches and then refer to table 2, 3, or 4, depending on the type of weir in use. These tables are for free-flow conditions and are applicable only to weirs installed and operated in the manner previously described. Submerged flow over

Table 2.—*Discharge table for rectangular weirs with complete contractions*

Head, H[1]		Discharge, Q, for crest length, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 10	1 3/16	0. 11	0. 16	0. 22	0. 33	0. 44	0. 62	0. 84	1. 05
. 11	1 5/16	. 12	. 18	. 25	. 37	. 50	. 73	. 97	1. 21
. 12	1 7/16	. 14	. 20	. 28	. 42	. 57	. 83	1. 10	1. 38
. 13	1 9/16	. 15	. 22	. 32	. 47	. 64	. 93	1. 24	1. 56
. 14	1 11/16	. 17	. 25	. 35	. 53	. 71	1. 04	1. 39	1. 74
. 15	1 13/16	. 19	. 28	. 39	. 58	. 79	1. 15	1. 54	1. 93
. 16	1 15/16	. 21	. 31	. 43	. 64	. 86	1. 27	1. 70	2. 12
. 17	2 1/16	. 23	. 34	. 47	. 70	. 95	1. 39	1. 86	2. 33
. 18	2 3/16	. 25	. 37	. 51	. 76	1. 03	1. 52	2. 03	2. 53
. 19	2 1/4	. 27	. 40	. 55	. 83	1. 11	1. 64	2. 20	2. 75
. 20	2 3/8	. 29	. 44	. 59	. 89	1. 19	1. 78	2. 37	2. 97
. 21	2 1/2	. 31	. 47	. 63	. 95	1. 28	1. 91	2. 55	3. 19
. 22	2 5/8	. 34	. 50	. 68	1. 02	1. 37	2. 05	2. 73	3. 42
. 23	2 3/4	. 36	. 54	. 72	1. 09	1. 46	2. 19	2. 92	3. 66
. 24	2 7/8	. 38	. 57	. 77	1. 16	1, 55	2. 33	3. 11	3. 90
. 25	3	. 40	. 61	. 82	1. 23	1. 65	2. 48	3. 31	4. 14
. 26	3 1/8	. 43	. 65	. 86	1. 31	1. 75	2. 63	3. 51	4. 39
. 27	3 1/4	. 45	. 68	. 91	1. 38	1. 85	2. 78	3. 71	4. 65
. 28	3 3/8	. 48	. 72	. 96	1. 46	1. 95	2. 93	3. 92	4. 91
. 29	3 1/2	. 50	. 76	1. 02	1. 53	2. 05	3. 09	4. 13	5. 17
. 30	3 5/8	. 53	. 80	1. 07	1. 61	2. 16	3. 25	4. 34	5. 44
. 31	3 3/4	. 55	. 84	1. 12	1. 69	2. 26	3. 41	4. 56	5. 71
. 32	3 13/16	. 58	. 88	1. 18	1. 77	2. 37	3. 58	4. 78	5. 99
. 33	3 15/16	. 61	. 92	1. 23	1. 86	2. 48	3. 75	5. 01	6. 27
. 34	4 1/16	. 63	. 96	1. 28	1. 94	2. 60	3. 92	5. 24	6. 56

.35	4 3/16	.66	1.00	1.34	2.02	2.71	4.09	5.47	6.85
.36	4 5/16	.69	1.04	1.40	2.11	2.82	4.26	5.70	7.14
.37	4 7/16	.72	1.08	1.45	2.20	2.94	4.44	5.94	7.44
.38	4 9/16	.74	1.13	1.51	2.28	3.06	4.62	6.18	7.74
.39	4 11/16	.77	1.17	1.57	2.37	3.18	4.80	6.43	8.05
.40	4 13/16	.80	1.21	1.63	2.46	3.30	4.99	6.67	8.36
.41	4 15/16	.83	1.26	1.69	2.55	3.42	5.17	6.92	8.67
.42	5 1/16	.86	1.30	1.75	2.65	3.54	5.36	7.18	8.99
.43	5 3/16	.89	1.35	1.81	2.74	3.67	5.55	7.43	9.31
.44	5 1/4	.92	1.40	1.88	2.83	3.80	5.75	7.69	9.63
.45	5 3/8	.96	1.44	1.94	2.93	3.93	5.94	7.95	9.96
.46	5 1/2	.99	1.49	2.00	3.03	4.05	6.14	8.22	10.3
.47	5 5/8	1.02	1.54	2.07	3.12	4.18	6.34	8.48	10.6
.48	5 3/4	1.05	1.59	2.13	3.22	4.32	6.54	8.75	11.0
.49	5 7/8	1.08	1.64	2.20	3.32	4.45	6.74	9.03	11.3
.50	6	1.11	1.68	2.26	3.42	4.58	6.95	9.30	11.7
.51	6 1/8	1.15	1.73	2.33	3.52	4.72	7.15	9.58	12.0
.52	6 1/4	1.18	1.78	2.40	3.62	4.86	7.36	9.86	12.4
.53	6 3/8	1.21	1.84	2.46	3.73	4.99	7.57	10.1	12.7
.54	6 1/2	1.25	1.89	2.53	3.83	5.13	7.79	10.4	13.1
.55	6 5/8	1.28	1.94	2.60	3.94	5.27	8.00	10.7	13.4
.56	6 3/4	1.31	1.99	2.67	4.04	5.42	8.22	11.0	13.8
.57	6 13/16	1.35	2.04	2.74	4.15	5.56	8.43	11.3	14.2
.58	6 15/16	1.38	2.09	2.81	4.26	5.70	8.65	11.6	14.5
.59	7 1/16	1.42	2.15	2.88	4.36	5.85	8.88	11.9	14.9
.60	7 3/16	1.45	2.20	2.96	4.47	6.00	9.10	12.2	15.3
.61	7 5/16	1.49	2.25	3.03	4.59	6.14	9.33	12.5	15.7
.62	7 7/16	1.52	2.31	3.10	4.69	6.29	9.55	12.8	16.1
.63	7 9/16	1.56	2.36	3.17	4.81	6.44	9.78	13.1	16.4
.64	7 11/16	1.60	2.42	3.25	4.92	6.59	10.0	13.4	16.8

See footnote at end of table.

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TABLE 2.—*Discharge table for rectangular weirs with complete contractions*—Continued

Head, H[1]		Discharge, Q, for crest length, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 65	7 13/16	1. 63	2. 47	3. 32	5. 03	6. 75	10. 2	13. 7	17. 2
. 66	7 15/16	1. 67	2. 53	3. 40	5. 15	6. 90	10. 5	14. 0	17. 6
. 67	8 1/16	1. 71	2. 59	3. 47	5. 26	7. 05	10. 7	14. 4	18. 0
. 68	8 3/16	1. 74	2. 64	3. 56	5. 38	7. 21	10. 9	14. 7	18. 4
. 69	8 1/4	1. 78	2. 70	3. 63	5. 49	7. 36	11. 2	15. 0	18. 8
. 70	8 3/8	1. 82	2. 76	3. 71	5. 61	7. 52	11. 4	15. 3	19. 2
. 71	8 1/2	1. 86	2. 81	3. 78	5. 73	7. 68	11. 7	15. 7	19. 6
. 72	8 5/8	1. 90	2. 87	3. 86	5. 85	7. 84	11. 9	16. 0	20. 1
. 73	8 3/4	1. 93	2. 93	3. 94	5. 97	8. 00	12. 2	16. 3	20. 5
. 74	8 7/8	1. 97	2. 99	4. 02	6. 09	8. 17	12. 4	16. 6	20. 9
. 75	9	2. 01	3. 05	4. 10	6. 21	8. 33	12. 7	17. 0	21. 3
. 76	9 1/8	2. 05	3. 11	4. 18	6. 33	8. 49	12. 9	17. 3	21. 7
. 77	9 1/4	2. 09	3. 17	4. 26	6. 45	8. 66	13. 2	17. 7	22. 2
. 78	9 3/8	2. 13	3. 23	4. 34	6. 58	8. 82	13. 4	18. 0	22. 6
. 79	9 1/2	2. 17	3. 29	4. 42	6. 70	8. 99	13. 7	18. 3	23. 0
. 80	9 5/8	2. 21	3. 35	4. 51	6. 83	9. 16	13. 9	18. 7	23. 4
. 81	9 3/4	2. 25	3. 41	4. 59	6. 95	9. 33	14. 2	19. 0	23. 9
. 82	9 13/16	2. 29	3. 47	4. 67	7. 08	9. 50	14. 4	19. 4	24. 3
. 83	9 15/16	2. 33	3. 54	4. 75	7. 21	9. 67	14. 7	19. 7	24. 8
. 84	10 1/16	2. 37	3. 60	4. 84	7. 33	9. 84	15. 0	20. 1	25. 2
. 85	10 3/16	2. 41	3. 66	4. 92	7. 46	10. 0	15. 2	20. 4	25. 7
. 86	10 5/16	2. 46	3. 72	5. 01	7. 59	10. 2	15. 5	20. 8	26. 1
. 87	10 7/16	2. 50	3. 79	5. 10	7. 72	10. 4	15. 7	21. 1	26. 6
. 88	10 9/16	2. 54	3. 85	5. 18	7. 85	10. 5	16. 0	21. 5	27. 0
. 89	10 11/16	2. 58	3. 92	5. 27	7. 99	10. 7	16. 3	21. 9	27. 5

.90	10 13/16	2.62	3.98	5.35	8.12	10.9	16.5	22.2	27.9
.91	10 15/16	2.67	4.05	5.44	8.25	11.1	16.8	22.6	28.4
.92	11 1/16	2.71	4.11	5.53	8.38	11.2	17.1	23.0	28.8
.93	11 3/16	2.75	4.18	5.62	8.52	11.4	17.4	23.3	29.3
.94	11 1/4	2.79	4.24	5.71	8.65	11.6	17.6	23.7	29.8
.95	11 3/8	2.84	4.31	5.80	8.79	11.8	17.9	24.1	30.2
.96	11 1/2	2.88	4.37	5.89	8.93	12.0	18.2	24.5	30.7
.97	11 5/8	2.93	4.44	5.98	9.06	12.2	18.5	24.8	31.2
.98	11 3/4	2.97	4.51	6.07	9.20	12.3	18.8	25.2	31.7
.99	11 7/8	3.01	4.57	6.15	9.34	12.5	19.0	25.6	32.2
1.00	12	3.06	4.64	6.25	9.48	12.7	19.3	26.0	32.6
1.01	12 1/8	------	4.71	6.34	9.62	12.9	19.6	26.4	33.1
1.02	12 1/4	------	4.78	6.43	9.76	13.1	19.9	26.7	33.6
1.03	12 3/8	------	4.85	6.52	9.90	13.3	20.2	27.1	34.1
1.04	12 1/2	------	4.92	6.62	10.0	13.5	20.5	27.5	34.6
1.05	12 5/8	------	4.98	6.71	10.2	13.7	20.7	27.9	35.1
1.06	12 3/4	------	5.05	6.80	10.3	13.8	21.0	28.3	35.6
1.07	12 13/16	------	5.12	6.90	10.5	14.0	21.3	28.7	36.1
1.08	12 15/16	------	5.20	6.99	10.6	14.2	21.6	29.1	36.6
1.09	13 1/16	------	5.26	7.09	10.8	14.4	21.9	29.5	37.1
1.10	13 3/16	------	5.34	7.19	10.9	14.6	22.2	29.9	37.6
1.11	13 5/16	------	5.41	7.28	11.0	14.8	22.5	30.3	38.1
1.12	13 7/16	------	5.48	7.38	11.2	15.0	22.8	30.7	38.6
1.13	13 9/16	------	5.55	7.47	11.3	15.2	23.1	31.1	39.1
1.14	13 11/16	------	5.62	7.57	11.5	15.4	23.4	31.5	39.6
1.15	13 13/16	------	5.69	7.66	11.6	15.6	23.7	31.9	40.1
1.16	13 15/16	------	5.77	7.76	11.8	15.8	24.0	32.3	40.6
1.17	14 1/16	------	5.84	7.86	11.9	16.0	24.3	32.7	41.2
1.18	14 3/16	------	5.91	7.96	12.1	16.2	24.6	33.1	41.7
1.19	14 1/4	------	5.98	8.06	12.2	16.4	24.9	33.6	42.2

See footnote at end of table.

TABLE 2.—*Discharge table for rectangular weirs with complete contractions*—Continued

Head, H[1]		Discharge, Q, for crest length, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
1. 20	14⅜	------	6. 06	8. 16	12. 4	16. 6	25. 2	34. 0	42. 7
1. 21	14½	------	6. 13	8. 26	12. 5	16. 8	25. 5	34. 4	43. 2
1. 22	14⅝	------	6. 20	8. 35	12. 7	17. 0	25. 8	34. 8	43. 8
1. 23	14¾	------	6. 28	8. 46	12. 8	17. 2	26. 2	35. 2	44. 3
1. 24	14⅞	------	6. 35	8. 56	13. 0	17. 4	26. 5	35. 6	44. 8
1. 25	15	------	6. 43	8. 66	13. 1	17. 6	26. 8	36. 1	45. 4
1. 26	15⅛	------	--------	--------	13. 3	17. 9	27. 1	36. 5	45. 9
1. 27	15¼	------	--------	--------	13. 4	18. 1	27. 4	36. 9	46. 4
1. 28	15⅜	------	--------	--------	13. 6	18. 3	27. 7	37. 3	47. 0
1. 29	15½	------	--------	--------	13. 8	18. 5	28. 0	37. 8	47. 5
1. 30	15⅝	------	--------	--------	13. 9	18. 7	28. 3	38. 2	48. 1
1. 31	15¾	------	--------	--------	14. 1	18. 9	28. 7	38. 6	48. 6
1. 32	15 13/16	------	--------	--------	14. 2	19. 1	29. 0	39. 1	49. 2
1. 33	15 15/16	------	--------	--------	14. 4	19. 3	29. 3	39. 5	49. 7
1. 34	16 1/16	------	--------	--------	14. 6	19. 6	29. 6	39. 9	50. 3
1. 35	16 3/16	------	--------	--------	14. 7	19. 8	30. 0	40. 4	50. 8
1. 36	16 5/16	------	--------	--------	14. 9	20. 0	30. 3	40. 8	51. 4
1. 37	16 7/16	------	--------	--------	15. 0	20. 2	30. 6	41. 3	51. 9
1. 38	16 9/16	------	--------	--------	15. 2	20. 4	30. 9	41. 7	52. 5
1. 39	16 11/16	------	--------	--------	15. 4	20. 6	31. 3	42. 1	53. 1
1. 40	16 13/16	------	--------	--------	15. 5	20. 9	31. 6	42. 6	53. 6
1. 41	16 15/16	------	--------	--------	15. 7	21. 1	31. 9	43. 0	54. 2
1. 42	17 1/16	------	--------	--------	15. 9	21. 3	32. 2	43. 5	54. 7
1. 43	17 3/16	------	--------	--------	16. 0	21. 5	32. 6	43. 9	55. 3
1. 44	17¼	------	--------	--------	16. 2	21. 7	32. 9	44. 4	55. 9

1. 45	17⅜	------	---------	---------	16. 3	22. 0	33. 2	44. 8	56. 5
1. 46	17½	------	---------	---------	16. 5	22. 2	33. 6	45. 3	57. 0
1. 47	17⅝	------	---------	---------	16. 7	22. 4	33. 9	45. 7	57. 6
1. 48	17¾	------	---------	---------	16. 9	22. 6	34. 2	46. 2	58. 2
1. 49	17⅞	------	---------	---------	17. 0	22. 9	34. 6	46. 6	58. 8
1. 50	18	------	---------	---------	17. 2	23. 1	34. 9	47. 1	59. 3

[1] Values of discharge for heads up to 0.20 foot (crest lengths 1, 1.5, 2, 3, and 4 feet) do not follow the formula, but are taken directly from the calibration curve. The discharge for heads 0.10 to 1.5 feet for the 6-, 8-, and 10-foot weirs are as computed by the formula $Q=3.33\ (L-0.2H)\ H^{3/2}$. See Mead, E., and Johnston, C. T. THE USE OF WATER IN IRRIGATION. U. S. Dept. Agr. Off. Expt. Sta. Bul. 86, 253 pp., illus. 1900.

TABLE 3.—*Discharge table for Cipolletti weirs with complete contractions*

Head, H[1]		Discharge, Q, for crest length, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 10	1 3/16	0. 11	0. 16	0. 23	0. 33	0. 44	0. 64	0. 85	1. 06
. 11	1 5/16	. 12	. 18	. 26	. 38	. 50	. 74	. 98	1. 23
. 12	1 7/16	. 14	. 21	. 29	. 43	. 57	. 84	1. 12	1. 40
. 13	1 9/16	. 16	. 24	. 32	. 48	. 64	. 95	1. 26	1. 58
. 14	1 11/16	. 17	. 26	. 36	. 54	. 71	1. 06	1. 41	1. 73
. 15	1 13/16	. 19	. 29	. 39	. 59	. 79	1. 17	1. 56	1. 96
. 16	1 15/16	. 21	. 32	. 43	. 65	. 87	1. 29	1. 72	2. 15
. 17	2 1/16	. 23	. 36	. 47	. 71	. 96	1. 41	1. 89	2. 36
. 18	2 3/16	. 25	. 39	. 51	. 77	1. 04	1. 54	2. 06	2. 57
. 19	2 1/4	. 28	. 42	. 56	. 83	1. 12	1. 67	2. 23	2. 79
. 20	2 3/8	. 30	. 45	. 60	. 90	1. 20	1. 81	2. 41	3. 01
. 21	2 1/2	. 32	. 48	. 64	. 97	1. 29	1. 94	2. 59	3. 24
. 22	2 5/8	. 35	. 52	. 69	1. 04	1. 38	2. 08	2. 78	3. 47
. 23	2 3/4	. 37	. 55	. 74	1. 11	1. 47	2. 23	2. 97	3. 71
. 24	2 7/8	. 39	. 59	. 79	1. 18	1. 57	2. 38	3. 17	3. 96
. 25	3	. 42	. 63	. 84	1. 25	1. 67	2. 53	3. 37	4. 21
. 26	3 1/8	. 45	. 67	. 89	1. 33	1. 77	2. 68	3. 57	4. 46
. 27	3 1/4	. 47	. 70	. 94	1. 40	1. 87	2. 83	3. 78	4. 72
. 28	3 3/8	. 50	. 74	. 99	1. 48	1. 97	2. 99	3. 99	4. 99
. 29	3 1/2	. 53	. 79	1. 04	1. 56	2. 08	3. 15	4. 21	5. 26
. 30	3 5/8	. 56	. 83	1. 10	1. 64	2. 19	3. 32	4. 43	5. 53
. 31	3 3/4	. 59	. 87	1. 15	1. 73	2. 30	3. 49	4. 65	5. 81
. 32	3 13/16	. 61	. 91	1. 21	1. 80	2. 41	3. 66	4. 88	6. 09
. 33	3 15/16	. 64	. 95	1. 27	1. 89	2. 52	3. 83	5. 11	6. 38
. 34	4 1/16	. 67	1. 00	1. 32	1. 98	2. 64	4. 00	5. 34	6. 67

.35	4 3/16	.70	1.04	1.38	2.07	2.75	4.18	5.58	6.97
.36	4 5/16	.73	1.09	1.44	2.16	2.87	4.36	5.82	7.27
.37	4 7/16	.77	1.13	1.50	2.25	2.99	4.55	6.06	7.58
.38	4 9/16	.80	1.18	1.57	2.34	3.11	4.73	6.31	7.89
.39	4 11/16	.83	1.23	1.63	2.43	3.24	4.92	6.56	8.20
.40	4 13/16	.87	1.28	1.69	2.53	3.36	5.11	6.81	8.52
.41	4 15/16	.90	1.32	1.76	2.62	3.49	5.30	7.07	8.84
.42	5 1/16	.93	1.37	1.82	2.72	3.61	5.50	7.33	9.16
.43	5 3/16	.97	1.42	1.89	2.81	3.74	5.70	7.59	9.49
.44	5 1/4	1.00	1.47	1.95	2.91	3.87	5.90	7.86	9.83
.45	5 3/8	1.04	1.53	2.02	3.01	4.01	6.10	8.13	10.2
.46	5 1/2	1.07	1.58	2.09	3.11	4.14	6.30	8.40	10.5
.47	5 5/8	1.11	1.63	2.16	3.21	4.28	6.51	8.68	10.8
.48	5 3/4	1.15	1.68	2.23	3.32	4.41	6.72	8.96	11.2
.49	5 7/8	1.18	1.74	2.30	3.42	4.55	6.93	9.24	11.5
.50	6	1.22	1.79	2.37	3.53	4.69	7.14	9.52	11.9
.51	6 1/8	1.26	1.85	2.44	3.64	4.83	7.36	9.81	12.3
.52	6 1/4	1.30	1.90	2.51	3.74	4.97	7.57	10.1	12.6
.53	6 3/8	1.34	1.96	2.59	3.85	5.12	7.79	10.4	13.0
.54	6 1/2	1.38	2.02	2.66	3.96	5.26	8.02	10.7	13.4
.55	6 5/8	1.42	2.07	2.74	4.07	5.41	8.24	11.0	13.7
.56	6 3/4	1.46	2.13	2.81	4.18	5.56	8.47	11.3	14.1
.57	6 13/16	1.50	2.19	2.89	4.30	5.71	8.69	11.6	14.5
.58	6 15/16	1.54	2.25	2.97	4.41	5.86	8.92	11.9	14.9
.59	7 1/16	1.58	2.31	3.05	4.53	6.01	9.15	12.2	15.3
.60	7 3/16	1.62	2.37	3.13	4.64	6.17	9.39	12.5	15.6
.61	7 5/16	1.67	2.43	3.20	4.76	6.32	9.62	12.8	16.0
.62	7 7/16	1.71	2.49	3.28	4.88	6.47	9.86	13.1	16.4
.63	7 9/16	1.75	2.55	3.37	5.00	6.63	10.1	13.5	16.8
.64	7 11/16	1.80	2.62	3.45	5.12	6.79	10.3	13.8	17.2

See footnote at end of table.

TABLE 3.—*Discharge table for Cipolletti weirs with complete contractions*—Continued

Head, H[1]		Discharge, Q, for crest length, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 65	7 13/16	1. 84	2. 68	3. 53	5. 24	6. 95	10. 6	14. 1	17. 6
. 66	7 15/16	1. 89	2. 75	3. 61	5. 36	7. 11	10. 8	14. 4	18. 1
. 67	8 1/16	1. 93	2. 81	3. 70	5. 48	7. 28	11. 1	14. 8	18. 5
. 68	8 3/16	1. 98	2. 87	3. 79	5. 61	7. 44	11. 3	15. 1	18. 9
. 69	8 1/4	2. 02	2. 94	3. 87	5. 73	7. 61	11. 6	15. 4	19. 3
. 70	8 3/8	2. 07	3. 01	3. 95	5. 86	7. 77	11. 8	15. 8	19. 7
. 71	8 1/2	2. 12	3. 07	4. 04	5. 99	7. 94	12. 1	16. 1	20. 1
. 72	8 5/8	2. 16	3. 14	4. 13	6. 12	8. 11	12. 3	16. 5	20. 6
. 73	8 3/4	2. 21	3. 21	4. 22	6. 24	8. 28	12. 6	16. 8	21. 0
. 74	8 7/8	2. 26	3. 28	4. 31	6. 38	8. 45	12. 9	17. 1	21. 4
. 75	9	2. 31	3. 35	4. 40	6. 51	8. 62	13. 1	17. 5	21. 9
. 76	9 1/8	2. 36	3. 42	4. 49	6. 64	8. 80	13. 4	17. 8	22. 3
. 77	9 1/4	2. 41	3. 49	4. 58	6. 77	8. 97	13. 6	18. 2	22. 7
. 78	9 3/8	2. 46	3. 56	4. 67	6. 90	9. 15	13. 9	18. 6	23. 2
. 79	9 1/2	2. 51	3. 63	4. 76	7. 04	9. 33	14. 2	18. 9	23. 6
. 80	9 5/8	2. 56	3. 70	4. 85	7. 18	9. 51	14. 5	19. 3	24. 1
. 81	9 3/4	2. 61	3. 77	4. 95	7. 31	9. 69	14. 7	19. 6	24. 5
. 82	9 13/16	2. 66	3. 84	5. 04	7. 45	9. 87	15. 0	20. 0	25. 0
. 83	9 15/16	2. 71	3. 92	5. 14	7. 59	10. 0	15. 3	20. 4	25. 5
. 84	10 1/16	2. 77	3. 99	5. 23	7. 73	10. 2	15. 6	20. 7	25. 9
. 85	10 3/16	2. 82	4. 07	5. 33	7. 87	10. 4	15. 8	21. 1	26. 4
. 86	10 5/16	2. 87	4. 14	5. 43	8. 01	10. 6	16. 1	21. 5	26. 9
. 87	10 7/16	2. 93	4. 22	5. 52	8. 15	10. 8	16. 4	21. 9	27. 3
. 88	10 9/16	2. 98	4. 29	5. 62	8. 30	11. 0	16. 7	22. 2	27. 8
. 89	10 11/16	3. 04	4. 37	5. 72	8. 44	11. 2	17. 0	22. 6	28. 3

.90	10 13/16	3.09	4.45	5.82	8.59	11.4	17.2	23.0	28.7
.91	10 15/16	3.15	4.53	5.92	8.73	11.6	17.5	23.4	29.2
.92	11 1/16	3.20	4.60	6.02	8.88	11.7	17.8	23.8	29.7
.93	11 3/16	3.26	4.68	6.13	9.03	11.9	18.1	24.2	30.2
.94	11 1/4	3.32	4.76	6.23	9.17	12.1	18.4	24.5	30.7
.95	11 3/8	3.37	4.84	6.33	9.32	12.3	18.7	24.9	31.2
.96	11 1/2	3.43	4.92	6.44	9.48	12.5	19.0	25.3	31.7
.97	11 5/8	3.49	5.00	6.55	9.62	12.7	19.3	25.7	32.2
.98	11 3/4	3.55	5.09	6.64	9.78	12.9	19.6	26.1	32.7
.99	11 7/8	3.61	5.17	6.75	9.93	13.1	19.9	26.5	33.2
1.00	12	3.67	5.25	6.86	10.1	13.3	20.2	26.9	33.7
1.01	12 1/8	------	5.33	6.96	10.2	13.5	20.5	27.3	34.2
1.02	12 1/4	------	5.42	7.07	10.4	13.7	20.8	27.7	34.7
1.03	12 3/8	------	5.50	7.18	10.6	13.9	21.1	28.2	35.2
1.04	12 1/2	------	5.59	7.29	10.7	14.2	21.4	28.6	35.7
1.05	12 5/8	------	5.67	7.40	10.9	14.4	21.7	29.0	36.2
1.06	12 3/4	------	5.76	7.51	11.0	14.6	22.0	29.4	36.7
1.07	12 13/16	------	5.84	7.62	11.2	14.8	22.4	29.8	37.3
1.08	12 15/16	------	5.93	7.73	11.4	15.0	22.7	30.2	37.8
1.09	13 1/16	------	6.02	7.84	11.5	15.2	23.0	30.6	38.3
1.10	13 3/16	------	6.11	7.96	11.7	15.4	23.3	31.1	38.8
1.11	13 5/16	------	6.20	8.07	11.8	15.6	23.6	31.5	39.4
1.12	13 7/16	------	6.29	8.18	12.0	15.8	23.9	31.9	39.9
1.13	13 9/16	------	6.38	8.29	12.2	16.0	24.3	32.4	40.4
1.14	13 11/16	------	6.47	8.41	12.3	16.3	24.6	32.8	41.0
1.15	13 13/16	------	6.56	8.53	12.5	16.5	24.9	33.2	41.5
1.16	13 15/16	------	6.65	8.65	12.7	16.7	25.2	33.6	42.1
1.17	14 1/16	------	6.74	8.76	12.8	16.9	25.6	34.1	42.6
1.18	14 3/16	------	6.83	8.88	13.0	17.2	25.9	34.5	43.2
1.19	14 1/4	------	6.93	9.00	13.2	17.4	26.2	35.0	43.7

See footenote at end of table.

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TABLE 3.—*Discharge table for Cipolletti weirs with complete contractions*—Continued

Head, H[1]		Discharge, *Q*, for crest length, *L*, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
1. 20	14⅜	------	7. 02	9. 12	13. 4	17. 6	26. 6	35. 4	44. 3
1. 21	14½	------	7. 11	9. 24	13. 5	17. 8	26. 9	35. 8	44. 8
1. 22	14⅝	------	7. 20	9. 36	13. 7	18. 0	27. 2	36. 3	45. 4
1. 23	14¾	------	7. 30	9. 48	13. 9	18. 3	27. 6	36. 7	45. 9
1. 24	14⅞	------	7. 40	9. 60	14. 0	18. 5	27. 9	37. 2	46. 5
1. 25	15	------	7. 49	9. 72	14. 2	18. 7	28. 2	37. 6	47. 1
1. 26	15⅛	------	--------	--------	14. 4	19. 0	28. 6	38. 1	47. 6
1. 27	15¼	------	--------	--------	14. 6	19. 2	28. 9	38. 5	48. 2
1. 28	15⅜	------	--------	--------	14. 7	19. 4	29. 3	39. 0	48. 8
1. 29	15½	------	--------	--------	14. 9	19. 6	29. 6	39. 5	49. 3
1. 30	15⅝	------	--------	--------	15. 1	19. 9	29. 9	39. 9	49. 9
1. 31	15¾	------	--------	--------	15. 3	20. 1	30. 3	40. 4	50. 5
1. 32	15 13/16	------	--------	--------	15. 5	20. 3	30. 6	40. 8	51. 1
1. 33	15 15/16	------	--------	--------	15. 6	20. 6	31. 0	41. 3	51. 6
1. 34	16 1/16	------	--------	--------	15. 8	20. 8	31. 3	41. 8	52. 2
1. 35	16 3/16	------	--------	--------	16. 0	21. 1	31. 7	42. 2	52. 8
1. 36	16 5/16	------	--------	--------	16. 2	21. 3	32. 0	42. 7	53. 4
1. 37	16 7/16	------	--------	--------	16. 4	21. 5	32. 4	43. 2	54. 0
1. 38	16 9/16	------	--------	--------	16. 6	21. 8	32. 7	43. 7	54. 6
1. 39	16 11/16	------	--------	--------	16. 8	22. 0	33. 1	44. 1	55. 2
1. 40	16 13/16	------	--------	--------	16. 9	22. 3	33. 5	44. 6	55. 8
1. 41	16 15/16	------	--------	--------	17. 1	22. 5	33. 8	45. 1	56. 4
1. 42	17 1/16	------	--------	--------	17. 3	22. 8	34. 2	45. 6	57. 0
1. 43	17 3/16	------	--------	--------	17. 5	23. 0	34. 6	46. 1	57. 6
1. 44	17¼	------	--------	--------	17. 7	23. 3	34. 9	46. 5	58. 2

1. 45	17⅜	------	--------	--------	17. 9	23. 5	35. 3	47. 0	58. 8
1. 46	17½	------	--------	--------	18. 1	23. 8	35. 6	47. 5	59. 4
1. 47	17⅝	------	--------	--------	18. 3	24. 0	36. 0	48. 0	60. 0
1. 48	17¾	------	--------	--------	18. 5	24. 3	36. 4	48. 5	60. 6
1. 49	17⅞	------	--------	--------	18. 7	24. 5	36. 7	49. 0	61. 2
1. 50	18	------	--------	--------	18. 9	24. 8	37. 1	49. 5	61. 8

[1] Values of discharge for heads up to 0.20 foot (crest lengths 1, 1.5, 2, 3, and 4 feet) do not follow the formula but are taken directly from the calibration curve. The discharge for heads 0.10 to 1.5 feet for the 6-, 8,- and 10-foot weirs are as computed by the formula $Q=3.367LH^{3/2}$. See MEAD, E., and JOHNSTON, C. I. THE USE OF WATER IN IRRIGATION. U. S. Dept. Agr. Off. Expt. Sta. Bul. 86, 253 pp., illus. 1900.

TABLE 4.—*Discharge table for 90° triangular-notch weir with complete contractions*

Head, H		Discharge, Q	Head, H		Discharge, Q	Head, H		Discharge, Q
Feet	*Inches*	*Second-feet*	*Feet*	*Inches*	*Second-feet*	*Feet*	*Inches*	*Second-feet*
0.15	1 13/16	0.022	0.55	6 5/8	0.564	0.95	11 3/8	2.19
.16	1 15/16	.025	.56	6 3/4	.590	.96	11 1/2	2.25
.17	2 1/16	.029	.57	6 13/16	.617	.97	11 5/8	2.31
.18	2 3/16	.034	.58	6 15/16	.644	.98	11 3/4	2.37
.19	2 1/4	.040	.59	7 1/16	.672	.99	11 7/8	2.43
.20	2 3/8	.046	.60	7 3/16	.700	1.00	12	2.49
.21	2 1/2	.052	.61	7 5/16	.730	1.01	12 1/8	2.55
.22	2 5/8	.058	.62	7 7/16	.760	1.02	12 1/4	2.61
.23	2 3/4	.065	.63	7 9/16	.790	1.03	12 3/8	2.68
.24	2 7/8	.072	.64	7 11/16	.822	1.04	12 1/2	2.74
.25	3	.080	.65	7 13/16	.854	1.05	12 5/8	2.81
.26	3 1/8	.088	.66	7 15/16	.887	1.06	12 3/4	2.87
.27	3 1/4	.096	.67	8 1/16	.921	1.07	12 13/16	2.94
.28	3 3/8	.105	.68	8 3/16	.955	1.08	12 15/16	3.01
.29	3 1/2	.115	.69	8 1/4	.991	1.09	13 1/16	3.08
.30	3 5/8	.125	.70	8 3/8	1.03	1.10	13 3/16	3.15
.31	3 3/4	.136	.71	8 1/2	1.06	1.11	13 5/16	3.22
.32	3 13/16	.147	.72	8 5/8	1.10	1.12	13 7/16	3.30
.33	3 15/16	.159	.73	8 3/4	1.14	1.13	13 9/16	3.37
.34	4 1/16	.171	.74	8 7/8	1.18	1.14	13 11/16	3.44
.35	4 3/16	.184	.75	9	1.22	1.15	13 13/16	3.52
.36	4 5/16	.197	.76	9 1/8	1.26	1.16	13 15/16	3.59
.37	4 7/16	.211	.77	9 1/4	1.30	1.17	14 1/16	3.67
.38	4 9/16	.225	.78	9 3/8	1.34	1.18	14 3/16	3.75
.39	4 11/16	.240	.79	9 1/2	1.39	1.19	14 1/4	3.83

.40	4 13/16	.256	.80	9 5/8	1.43	1.20	14 3/8	3.91
.41	4 15/16	.272	.81	9 3/4	1.48	1.21	14 1/2	3.99
.42	5 1/16	.289	.82	9 13/16	1.52	1.22	14 5/8	4.07
.43	5 3/16	.306	.83	9 15/16	1.57	1.23	14 3/4	4.16
.44	5 1/4	.324	.84	10 1/16	1.61	1.24	14 7/8	4.24
.45	5 3/8	.343	.85	10 3/16	1.66	1.25	15	4.33
.46	5 1/2	.362	.86	10 5/16	1.71	1.26	15 1/8	4.42
.47	5 5/8	.382	.87	10 7/16	1.76	1.27	15 1/4	4.51
.48	5 3/4	.403	.88	10 9/16	1.81	1.28	15 3/8	4.60
.49	5 7/8	.424	.89	10 11/16	1.86	1.29	15 1/2	4.69
.50	6	.445	.90	10 13/16	1.92	1.30	15 5/8	4.78
.51	6 1/8	.468	.91	10 15/16	1.97	1.31	15 3/4	4.87
.52	6 1/4	.491	.92	11 1/16	2.02	1.32	15 13/16	4.96
.53	6 3/8	.515	.93	11 3/16	2.08	1.33	15 15/16	5.06
.54	6 1/2	.539	.94	11 1/4	2.13	1.34	16 1/16	5.15

weirs is generally unsatisfactory, and for this reason the subject is omitted from the discussion of weirs.

Limitations of Weirs

The weir, when properly set and maintained, is considered one of the most accurate means of measuring flowing water, but when operated under field conditions such as are found in irrigation practice, it may be considerably in error owing to neglected maintenance and other causes. In order that a weir may continue to measure water accurately, the side and bottom-contraction distances and the proper velocity of approach conditions must be maintained. Water flowing in earth channels usually carries sand and sediment which accumulate in the weir box or pond upstream from the weir bulkhead. This filling eventually destroys the standard bottom-contraction distance and causes the weir to overregister because of the increased velocity of approach. The error thus caused in the rate of discharge is slight at first, but when the surface of the deposit is raised to the elevation of the crest, the increase in discharge over that indicated by the head is an appreciable amount.

Where accurate measurements of the flow are required, wooden crest and sides for the weir notch are not recommended, because natural wear and deterioration soon dull the edges of the notch and result in an actual discharge greater than the one indicated A weir box built to provide proper contraction distances and extra length of floor to serve as an apron for preventing scour require somewhat more material than that needed for a simple bulkhead structure.

In many cases the weir cannot be used as a free-flow measuring device because of the flat grade of the channel. The accompanying weir-discharge tables are useful only if the loss of head at the weir is not less than the measured depth of the water over the crest plus an additional 0.1 foot for the aeration of the nappe. If the surface of the water downstream from the weir rises above the crest level the flow is submerged, and the actual discharge is less than that indicated in the table for the particular head (H). The filling of deposit in the weir pond, rounded edges of the crest and sides, a downstream inclination of the wooden notch with bevel on upstream side of bulkhead, downstream water surface at or slightly above the crest, nappe confined to prevent aeration, all tend to increase the rate of flow over the notch. High downstream water surface resists the flow through the notch and reduces the discharge.

Extended discussion of weirs without end contractions is not within the scope of this bulletin. For this type of weir two common settings have been used: First, where the end contractions are reduced to zero by having the width of the approach channel equal to that of the crest length and the width of the channel downstream great enough to permit complete aeration of the nappe; second, where the side walls of the structure are parallel and the weir bulkhead is placed well back from the lower end. For this combination the nappe must be aerated by suitable air vents. The standard weir with complete contractions is most generally used.

THE PARSHALL MEASURING FLUME

The Parshall measuring flume is a device intended primarily for use in irrigation practice, the smaller sizes being especially suited to the measurement of farm deliveries. It consists of a converging section, a throat, and a diverging section, with the floor of the converging, or upstream section, level both longitudinally and transversely. The floor of the throat is inclined downward at a slope of 9 inches vertical to 24 inches horizontal, and the floor of the diverging or downstream section inclines upward at a slope of 6 inches vertical to 36 inches horizontal, for throat widths ranging from 1 to 8 feet. For these sizes the elevation of the floor at the downstream end of the flume is 3 inches lower than the crest, which is the line where the floor of the converging section joins the inclined floor of the throat section. The size of flume (*W*) is taken as the horizontal distance between the vertical parallel walls of the throat and is identical with the length of the crest. For the range of sizes 1 to 8 feet, the length of throat is 2 feet and the length of the diverging section 3 feet. For the smaller flumes—3-inch, 6-inch, and 9-inch—the ratios of dimensions depart somewhat from those applicable to the larger flumes. The slope of the throat floor, however, is the same for all sizes. Table 5 gives the appropriate dimensions of the several throat widths, the lettered columns referring to the dimensions similarly identified in figure 2.

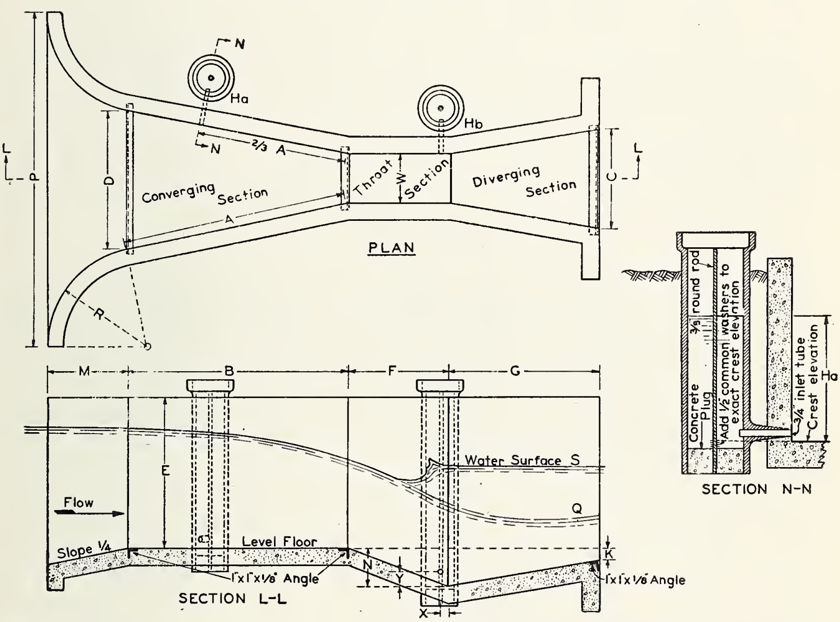

FIGURE 2.—Plan and elevation of a concrete Parshall measuring flume showing lettered dimensions as follows: *W*, size of flume, in inches or feet; *A*, length of side wall of converging section; 2/3 A, distance back from end of crest to gage point; *B*, axial length of converging section; *C*, width of downstream end of flume; *D*, width of upstream end of flume; *E*, depth of flume; *F*, length of throat; *G*, length of diverging section; *K*, difference in elevation between lower end of flume and crest; *M*, length of approach floor; *N*, depth of depression in throat below crest; *P*, width between ends of curved wing walls; *R*, radius of curved wing wall; *X*, horizontal distance to H_b gage point from low point in throat; *Y*, vertical distance to H_b gage point from low point in throat. See table 5 for actual dimensions for various sizes of flume.

TABLE 5.—*Dimensions and capacities of the Parshall measuring flume, for various throat widths, W*

[Letters refer to dimensions, fig. 2]

W	A	2/3 A	B	C	D	E	F	G	K	N	R	M	P	X	Y	Free-flow capacity	
																Minimum	Maximum
Ft. In.	*Ft. In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*In.*	*In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*In.*	*In.*	*Sec.-ft.*	*Sec.-ft.*
0 3	1 6⅜	1 ¼	1 6	0 7	0 10³⁄₁₆	2 0	0 6	1 0	1	2¼	1 4	1 0	2 6¼	1	1½	0.03	1.9
0 6	2 ⁷⁄₁₆	1 4⁵⁄₁₆	2 0	1 3½	1 3⅝	2 0	1 0	2 0	3	4½	1 4	1 0	2 11½	2	3	.05	3.9
0 9	2 10⅝	1 11⅛	2 10	1 3	1 10⅝	2 6	1 0	1 6	3	4½	1 4	1 0	3 6½	2	3	.09	8.9
1 0	4 6	3 0	4 4⅞	2 0	2 9¼	3 0	2 0	3 0	3	9	1 8	1 3	4 10¾	2	3	.11	16.1
1 6	4 9	3 2	4 7⅞	2 6	3 4⅜	3 0	2 0	3 0	3	9	1 8	1 3	5 6	2	3	.15	24.6
2 0	5 0	3 4	4 10⅞	3 0	3 11½	3 0	2 0	3 0	3	9	1 8	1 3	6 1	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	1 8	1 3	7 3½	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 0	1 6	8 10¾	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 0	1 6	10 1¼	2	3	1.6	85.6
6 0	7 0	4 8	6 10⅜	7 0	8 9	3 0	2 0	3 0	3	9	2 0	1 6	11 3½	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 0	1 6	12 6	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 0	1 6	13 8¼	2	3	3.5	139.5

Discharge through the Parshall measuring flume can occur under two different conditions of flow: First, where there is no submergence, called free flow; and second, where the elevation of the water surface downstream from the flume is high enough to retard the rate of discharge, a condition called submerged flow. To determine the rate of discharge through this device, two depth gages, H_a and H_b, are provided as shown in figure 2. The upper gage H_a, is located at a point two-thirds the length of the converging section, A, measured back from the end point of the crest; the lower gage, H_b, is near the downstream end of the throat section. Both gages, H_a and H_b, are to be set with the zero points at the mean elevation of the crest of the flume.

Where the correct size of the flume is chosen, the velocity of approach is automatically controlled. This is realized in selecting a width of throat capable of accommodating the full flow to be measured and at the same time, because of the narrowness of the throat which resists the flow, causes the depth upstream to be increased. The result is a larger cross-sectional area of the approaching stream and hence a reduction in velocity.

A distinct advantage of the Parshall measuring flume is its ability to operate as a single-head device with a minimum loss of head. For flumes and weirs having equal crest lengths it is found that the loss of head, when both are operating under free flow at the same discharge, is only about one-fourth as much for the flume as for the weir. The ordinary rating flume, if properly maintained, is a means of measuring flowing water in channels with the least loss of head; however, because the device is unreliable, it is seldom used for farm deliveries.

Free Flow

Free flow is the condition under which the rate of discharge is dependent solely upon the length of crest and the depth of water at the gage point H_a, in the converging section, this being similar to a weir where only the length of crest and head are involved in the computation of the discharge. One of the important characteristics of the Parshall measuring flume is its ability to withstand a relatively high degree of submergence, over a wide range of backwater conditions downstream from the structure, without reduction in the indicated rate of free flow. The stream passing through the throat and diverging sections of the flume can flow at two different stages: First, the condition where the water at high velocity moves in a thin sheet conforming closely to the dip at the lower end of the throat (indicated by Q in figure 2); second, the condition where the backwater raises the water surface to elevation S, causing a ripple or wave to form at or just downstream from the end of the throat.

For this higher stage, S, there occurs a marked reduction in the velocity of the water as it leaves the lower end of the flume. Where the flow is submerged at 60 to 70 percent, the exit velocity is much modified, the erosion effect on the bed and banks of the channel is less severe, and the total loss of head through the structure is lessened, which, under some conditions, is a distinct advantage.

If the ratio of the H_b head to the H_a head is 0.7 or less for the 1- to 8-foot flumes, or 0.6 for the 3-, 6-, and 9-inch flumes, the rate of discharge is that given in table 6 for the particular value of the H_a

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TABLE 6.—*Free-flow discharge table for Parshall measuring flume*

[Letters, H_a, and W, refer to figure 2. To convert decimal fractions of a foot to inches and fractions, see corresponding units in table 2]

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—											
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
	Second-feet	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 10	0. 028	0. 05	0. 09	0. 11	0. 15	-----	-----	-----	-----	-----	-----	-----
. 11	. 033	. 06	. 10	. 12	. 18	-----	-----	-----	-----	-----	-----	-----
. 12	. 037	. 07	. 12	. 14	. 21	-----	-----	-----	-----	-----	-----	-----
. 13	. 042	. 08	. 14	. 16	. 24	-----	-----	-----	-----	-----	-----	-----
. 14	. 047	. 09	. 15	. 18	. 27	-----	-----	-----	-----	-----	-----	-----
. 15	. 053	. 10	. 17	. 20	. 30	0. 42	0. 61	-----	-----	-----	-----	-----
. 16	. 058	. 11	. 19	. 23	. 34	. 47	. 68	-----	-----	-----	-----	-----
. 17	. 064	. 12	. 20	. 26	. 38	. 51	. 75	-----	-----	-----	-----	-----
. 18	. 070	. 14	. 22	. 29	. 42	. 56	. 82	-----	-----	-----	-----	-----
. 19	. 076	. 15	. 24	. 32	. 46	. 61	. 89	-----	-----	-----	-----	-----
. 20	. 082	. 16	. 26	. 35	. 51	. 66	. 97	1. 26	1. 55	-----	-----	-----
. 21	. 089	. 18	. 28	. 37	. 55	. 71	1. 04	1. 36	1. 68	-----	-----	-----
. 22	. 095	. 19	. 30	. 40	. 59	. 77	1. 12	1. 47	1. 81	-----	-----	-----
. 23	. 102	. 20	. 32	. 43	. 63	. 82	1. 20	1. 58	1. 94	-----	-----	-----
. 24	. 109	. 22	. 35	. 46	. 67	. 88	1. 28	1. 69	2. 08	-----	-----	-----
. 25	. 117	. 23	. 37	. 49	. 71	. 93	1. 37	1. 80	2. 22	2. 63	3. 02	3. 46
. 26	. 124	. 25	. 39	. 51	. 76	. 99	1. 46	1. 91	2. 36	2. 80	3. 25	3. 68
. 27	. 131	. 26	. 41	. 54	. 80	1. 05	1. 55	2. 03	2. 50	2. 97	3. 44	3. 90
. 28	. 138	. 28	. 44	. 58	. 85	1. 11	1. 64	2. 15	2. 65	3. 15	3. 65	4. 13
. 29	. 146	. 29	. 46	. 61	. 90	1. 18	1. 73	2. 27	2. 80	3. 33	3. 85	4. 37

.30	.154	.31	.49	.64	.94	1.24	1.82	2.39	2.96	3.52	4.08	4.62
.31	.162	.32	.51	.68	.99	1.30	1.92	2.52	3.12	3.71	4.30	4.88
.32	.170	.34	.54	.71	1.04	1.37	2.02	2.65	3.28	3.90	4.52	5.13
.33	.179	.36	.56	.74	1.09	1.44	2.12	2.78	3.44	4.10	4.75	5.39
.34	.187	.38	.59	.77	1.14	1.50	2.22	2.92	3.61	4.30	4.98	5.66
.35	.196	.39	.62	.80	1.19	1.57	2.32	3.06	3.78	4.50	5.22	5.93
.36	.205	.41	.64	.84	1.25	1.64	2.42	3.20	3.95	4.71	5.46	6.20
.37	.213	.43	.67	.88	1.30	1.72	2.53	3.34	4.13	4.92	5.70	6.48
.38	.222	.45	.70	.92	1.36	1.79	2.64	3.48	4.31	5.13	5.95	6.76
.39	.231	.47	.73	.95	1.41	1.86	2.75	3.62	4.49	5.35	6.20	7.05
.40	.241	.48	.76	.99	1.47	1.93	2.86	3.77	4.68	5.57	6.46	7.34
.41	.250	.50	.78	1.03	1.53	2.01	2.97	3.92	4.86	5.80	6.72	7.64
.42	.260	.52	.81	1.07	1.58	2.09	3.08	4.07	5.05	6.02	6.98	7.94
.43	.269	.54	.84	1.11	1.64	2.16	3.29	4.22	5.24	6.25	7.25	8.24
.44	.279	.56	.87	1.15	1.70	2.24	3.32	4.38	5.43	6.48	7.52	8.55
.45	.289	.58	.90	1.19	1.76	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.46	.299	.61	.94	1.23	1.82	2.40	3.56	4.70	5.83	6.96	8.08	9.19
.47	.309	.63	.97	1.27	1.88	2.48	3.68	4.86	6.03	7.20	8.36	9.51
.48	.319	.65	1.00	1.31	1.94	2.57	3.80	5.03	6.24	7.44	8.65	9.84
.49	.329	.67	1.03	1.35	2.00	2.65	3.92	5.20	6.45	7.69	8.94	10.2
.50	.339	.69	1.06	1.39	2.06	2.73	4.05	5.36	6.66	7.94	9.23	10.5
.51	.350	.71	1.10	1.44	2.13	2.82	4.18	5.53	6.87	8.20	9.53	10.9
.52	.361	.73	1.13	1.48	2.19	2.90	4.31	5.70	7.09	8.46	9.83	11.2
.53	.371	.76	1.16	1.52	2.25	2.99	4.44	5.88	7.30	8.72	10.1	11.5
.54	.382	.78	1.20	1.57	2.32	3.08	4.57	6.05	7.52	8.98	10.5	11.9
.55	.393	.80	1.23	1.62	2.39	3.17	4.70	6.23	7.74	9.25	10.8	12.2
.56	.404	.82	1.26	1.66	2.45	3.26	4.84	6.41	7.97	9.52	11.1	12.6
.57	.415	.85	1.30	1.70	2.52	3.35	4.98	6.59	8.20	9.79	11.4	13.0
.58	.427	.87	1.33	1.75	2.59	3.44	5.11	6.77	8.43	10.1	11.7	13.3
.59	.438	.89	1.37	1.80	2.66	3.53	5.25	6.96	8.66	10.4	12.0	13.7

TABLE 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

[Letters, H_a, and W, refer to figure 2. To convert decimal fractions of a foot to inches and fractions, see corresponding units in table 2]

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—											
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
	Second-feet	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 60	0. 450	0. 92	1. 40	1. 84	2. 73	3. 62	5. 39	7. 15	8. 89	10. 6	12. 4	14. 1
. 61	. 462	. 94	1. 44	1. 88	2. 80	3. 72	5. 53	7. 34	9. 13	10. 9	12. 7	14. 5
. 62	. 474	. 97	1. 48	1. 93	2. 87	3. 81	5. 68	7. 53	9. 37	11. 2	13. 0	14. 8
. 63	. 485	. 99	1. 51	1. 98	2. 95	3. 91	5. 82	7. 72	9. 61	11. 5	13. 4	15. 2
. 64	. 497	1. 02	1. 55	2. 03	3. 02	4. 01	5. 97	7. 91	9. 85	11. 8	13. 7	15. 6
. 65	. 509	1. 04	1. 59	2. 08	3. 09	4. 11	6. 12	8. 11	10. 1	12. 1	14. 1	16. 0
. 66	. 522	1. 07	1. 63	2. 13	3. 17	4. 20	6. 26	8. 31	10. 3	12. 4	14. 4	16. 4
. 67	. 534	1. 10	1. 66	2. 18	3. 24	4. 30	6. 41	8. 51	10. 6	12. 7	14. 8	16. 8
. 68	. 546	1. 12	1. 70	2. 23	3. 31	4. 40	6. 56	8. 71	10. 8	13. 0	15. 1	17. 2
. 69	. 558	1. 15	1. 74	2. 28	3. 39	4. 50	6. 71	8. 91	11. 1	13. 3	15. 5	17. 6
. 70	. 571	1. 17	1. 78	2. 33	3. 46	4. 60	6. 86	9. 11	11. 4	13. 6	15. 8	18. 0
. 71	. 584	1. 20	1. 82	2. 38	3. 54	4. 70	7. 02	9. 32	11. 6	13. 9	16. 2	18. 5
. 72	. 597	1. 23	1. 86	2. 43	3. 62	4. 81	7. 17	9. 53	11. 9	14. 2	16. 6	18. 9
. 73	. 610	1. 26	1. 90	2. 48	3. 69	4. 91	7. 33	9. 74	12. 1	14. 5	16. 9	19. 3
. 74	. 623	1. 28	1. 94	2. 53	3. 77	5. 02	7. 49	9. 95	12. 4	14. 9	17. 3	19. 7
. 75	. 636	1. 31	1. 98	2. 58	3. 85	5. 12	7. 65	10. 2	12. 7	15. 2	17. 7	20. 1
. 76	. 649	1. 34	2. 02	2. 63	3. 93	5. 23	7. 81	10. 4	12. 9	15. 5	18. 0	20. 6
. 77	. 662	1. 36	2. 06	2. 68	4. 01	5. 34	7. 97	10. 6	13. 2	15. 8	18. 4	21. 0
. 78	. 675	1. 39	2. 10	2. 74	4. 09	5. 44	8. 13	10. 8	13. 5	16. 2	18. 8	21. 5
. 79	. 689	1. 42	2. 14	2. 80	4. 17	5. 55	8. 30	11. 0	13. 8	16. 5	19. 2	21. 9

.80	.702	1.45	2.18	2.85	4.26	5.66	8.46	11.3	14.0	16.8	19.6	22.4
.81	.716	1.48	2.22	2.90	4.34	5.77	8.63	11.5	14.3	17.2	20.0	22.8
.82	.730	1.50	2.27	2.96	4.42	5.88	8.79	11.7	14.6	17.5	20.4	23.3
.83	.744	1.53	2.31	3.02	4.50	6.00	8.96	11.9	14.9	17.8	20.8	23.7
.84	.757	1.56	2.35	3.07	4.59	6.11	9.13	12.2	15.2	18.2	21.2	24.2
.85	.771	1.59	2.39	3.12	4.67	6.22	9.30	12.4	15.5	18.5	21.6	24.6
.86	.786	1.62	2.44	3.18	4.76	6.33	9.48	12.6	15.8	18.9	22.0	25.1
.87	.800	1.65	2.48	3.24	4.84	6.44	9.65	12.8	16.0	19.2	22.4	25.6
.88	.814	1.68	2.52	3.29	4.93	6.56	9.82	13.1	16.3	19.6	22.8	26.1
.89	.828	1.71	2.57	3.35	5.01	6.68	10.0	13.3	16.6	19.9	23.2	26.5
.90	.843	1.74	2.61	3.41	5.10	6.80	10.2	13.6	16.9	20.3	23.7	27.0
.91	.858	1.77	2.66	3.46	5.19	6.92	10.4	13.8	17.2	20.7	24.1	27.5
.92	.872	1.81	2.70	3.52	5.28	7.03	10.5	14.0	17.5	21.0	24.5	28.0
.93	.887	1.84	2.75	3.58	5.37	7.15	10.7	14.3	17.8	21.4	24.9	28.5
.94	.902	1.87	2.79	3.64	5.46	7.27	10.9	14.5	18.1	21.8	25.4	29.0
.95	.916	1.90	2.84	3.70	5.55	7.39	11.1	14.8	18.4	22.1	25.8	29.5
.96	.931	1.93	2.88	3.76	5.64	7.51	11.3	15.0	18.8	22.5	26.2	30.0
.97	.946	1.97	2.93	3.82	5.73	7.63	11.4	15.3	19.1	22.9	26.7	30.5
.98	.961	2.00	2.98	3.88	5.82	7.75	11.6	15.5	19.4	23.2	27.1	31.0
.99	.977	2.03	3.02	3.94	5.91	7.88	11.8	15.8	19.7	23.6	27.6	31.5
1.00	.992	2.06	3.07	4.00	6.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0
1.01	1.01	2.09	3.12	4.06	6.09	8.12	12.2	16.3	20.3	24.4	28.5	32.5
1.02	1.02	2.12	3.17	4.12	6.19	8.25	12.4	16.5	20.6	24.8	28.9	33.0
1.03	1.04	2.16	3.21	4.18	6.28	8.38	12.6	16.8	21.0	25.2	29.4	33.6
1.04	1.05	2.19	3.26	4.25	6.37	8.50	12.8	17.0	21.3	25.6	29.8	34.1
1.05	1.07	2.22	3.31	4.31	6.47	8.63	13.0	17.3	21.6	25.9	30.3	34.6
1.06	1.09	2.26	3.36	4.37	6.56	8.76	13.2	17.5	21.9	26.3	30.7	35.1
1.07	1.10	2.29	3.40	4.43	6.66	8.88	13.3	17.8	22.3	26.7	31.2	35.7
1.08	1.12	2.32	3.45	4.50	6.75	9.01	13.5	18.1	22.6	27.1	31.7	36.2
1.09	1.13	2.36	3.50	4.56	6.85	9.14	13.7	18.3	22.9	27.5	32.1	36.8

TABLE 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

[Letters, H_a, and W, refer to figure 2. To convert decimal fractions of a foot to inches and fractions, see corresponding units in table 2]

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—											
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
	Second-feet	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
1. 10	1. 15	2. 40	3. 55	4. 62	6. 95	9. 27	13. 9	18. 6	23. 3	27. 9	32. 6	37. 3
1. 11	1. 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	1. 18	2. 46	3. 65	4. 75	7. 14	9. 54	14. 3	19. 1	23. 9	28. 8	33. 6	38. 4
1. 13	1. 20	2. 50	3. 70	4. 82	7. 24	9. 67	14. 5	19. 4	24. 3	29. 2	34. 1	38. 9
1. 14	1. 21	2. 53	3. 75	4. 88	7. 34	9. 80	14. 7	19. 7	24. 6	29. 6	34. 5	39. 5
1. 15	1. 22	2. 57	3. 80	4. 94	7. 44	9. 94	14. 9	19. 9	25. 0	30. 0	35. 0	40. 1
1. 16	1. 25	2. 60	3. 85	5. 01	7. 54	10. 1	15. 1	20. 2	25. 3	30. 4	35. 5	40. 6
1. 17	1. 26	2. 64	3. 90	5. 08	7. 64	10. 2	15. 3	20. 5	25. 7	30. 8	36. 0	41. 2
1. 18	1. 28	2. 68	3. 95	5. 15	7. 74	10. 3	15. 6	20. 8	26. 0	31. 3	36. 5	41. 8
1. 19	1. 30	2. 71	4. 01	5. 21	7. 84	10. 5	15. 8	21. 1	26. 4	31. 7	37. 0	42. 3
1. 20	1. 32	2. 75	4. 06	5. 28	7. 94	10. 6	16. 0	21. 3	26. 7	32. 1	37. 5	42. 9
1. 21	1. 33	2. 78	4. 11	5. 34	8. 05	10. 8	16. 2	21. 6	27. 1	32. 5	38. 0	43. 5
1. 22	1. 35	2. 82	4. 16	5. 41	8. 15	10. 9	16. 4	21. 9	27. 4	33. 0	38. 5	44. 1
1. 23	1. 37	2. 86	4. 22	5. 48	8. 25	11. 0	16. 6	22. 2	27. 8	33. 4	39. 0	44. 6
1. 24	1. 38	2. 89	4. 27	5. 55	8. 36	11. 2	16. 8	22. 5	28. 1	33. 8	39. 5	45. 2
1. 25	1. 40	2. 93	4. 32	5. 62	8. 46	11. 3	17. 0	22. 8	28. 5	34. 3	40. 0	45. 8
1. 26	1. 42	2. 97	4. 37	5. 69	8. 56	11. 5	17. 2	23. 0	28. 9	34. 7	40. 5	46. 4
1. 27	1. 44	3. 01	4. 43	5. 76	8. 67	11. 6	17. 4	23. 3	29. 2	35. 1	41. 1	47. 0
1. 28	1. 45	3. 04	4. 48	5. 82	8. 77	11. 7	17. 7	23. 6	29. 6	35. 6	41. 6	47. 6
1. 29	1. 47	3. 08	4. 53	5. 89	8. 88	11. 9	17. 9	23. 9	30. 0	36. 0	42. 1	48. 2

1.30	1.49	3.12	4.59	5.96	8.99	12.0	18.1	24.2	30.3	36.5	42.6	48.8
1.31	1.50	3.16	4.64	6.03	9.09	12.2	18.3	24.5	30.7	36.9	43.1	49.4
1.32	1.52	3.19	4.69	6.10	9.20	12.3	18.5	24.8	31.1	37.4	43.7	50.0
1.33	1.54	3.23	4.75	6.18	9.30	12.4	18.8	25.1	31.4	37.8	44.2	50.6
1.34	1.56	3.27	4.80	6.25	9.41	12.6	19.0	25.4	31.8	38.3	44.7	51.2
1.35	1.58	3.31	4.86	6.32	9.52	12.7	19.2	25.7	32.2	38.7	45.3	51.8
1.36	1.59	3.35	4.92	6.39	9.63	12.9	19.4	26.0	32.6	39.2	45.8	52.5
1.37	1.61	3.39	4.97	6.46	9.74	13.0	19.6	26.3	33.0	39.7	46.4	53.1
1.38	1.63	3.43	5.03	6.53	9.85	13.2	19.9	26.6	33.3	40.1	46.9	53.7
1.39	1.65	3.47	5.08	6.60	9.96	13.3	20.1	26.9	33.7	40.6	47.4	54.3
1.40	1.67	3.51	5.14	6.68	10.1	13.5	20.3	27.2	34.1	41.1	48.0	55.0
1.41	1.69	3.55	5.19	6.75	10.2	13.6	20.6	27.5	34.5	41.5	48.5	55.6
1.42	1.70	3.59	5.25	6.82	10.3	13.8	20.8	27.8	34.9	42.0	49.1	56.2
1.43	1.72	3.63	5.31	6.89	10.4	13.9	21.0	28.1	35.3	42.5	49.6	56.9
1.44	1.74	3.67	5.37	6.97	10.5	14.1	21.2	28.5	35.7	42.9	50.2	57.5
1.45	1.76	3.71	5.42	7.04	10.6	14.2	21.5	28.8	36.1	43.4	50.8	58.1
1.46	1.78	3.75	5.48	7.12	10.7	14.4	21.7	29.1	36.5	43.9	51.3	58.8
1.47	1.80	3.79	5.54	7.19	10.8	14.5	21.9	29.4	36.9	44.4	51.9	59.4
1.48	1.82	3.83	5.59	7.26	11.0	14.7	22.2	29.7	37.3	44.9	52.5	60.1
1.49	1.84	3.87	5.65	7.34	11.1	14.9	22.4	30.0	37.7	45.3	53.0	60.7
1.50	1.86	3.91	5.71	7.41	11.2	15.0	22.6	30.3	38.1	45.8	53.6	61.4
1.51	...	...	5.77	7.49	11.3	15.2	22.9	30.7	38.5	46.3	54.2	62.1
1.52	...	...	5.83	7.57	11.4	15.3	23.1	31.0	38.9	46.8	54.7	62.7
1.53	...	...	5.89	7.64	11.5	15.5	23.4	31.3	39.3	47.3	55.3	63.4
1.54	...	...	5.94	7.72	11.7	15.6	23.6	31.6	39.7	47.8	55.9	64.0
1.55	...	...	6.00	7.80	11.8	15.8	23.8	32.0	40.1	48.3	56.5	64.7
1.56	...	...	6.06	7.87	11.9	15.9	24.1	32.3	40.5	48.8	57.1	65.4
1.57	...	...	6.12	7.95	12.0	16.1	24.3	32.6	40.9	49.3	57.7	66.1
1.58	...	...	6.18	8.02	12.1	16.3	24.6	32.9	41.3	49.8	58.2	66.7
1.59	...	...	6.24	8.10	12.2	16.4	24.8	33.3	41.8	50.3	58.8	67.4

Table 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

[Letters, H_a, and W, refer to figure 2. To convert decimal fractions of a foot to inches and fractions, see corresponding units in table 2]

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—											
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
	Second-feet	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
1. 60	----	----	6. 31	8. 18	12. 4	16. 6	25. 1	33. 6	42. 2	50. 8	59. 4	68. 1
1. 61	----	----	6. 37	8. 26	12. 5	16. 7	25. 3	33. 9	42. 6	51. 3	60. 0	68. 8
1. 62	----	----	6. 43	8. 34	12. 6	16. 9	25. 5	34. 3	43. 0	51. 8	60. 6	69. 5
1. 63	----	----	6. 49	8. 42	12. 7	17. 1	25. 8	34. 6	43. 4	52. 3	61. 2	70. 2
1. 64	----	----	6. 55	8. 49	12. 8	17. 2	26. 0	34. 9	43. 9	52. 8	61. 8	70. 9
1. 65	----	----	6. 61	8. 57	13. 0	17. 4	26. 3	35. 3	44. 3	53. 3	62. 4	71. 6
1. 66	----	----	6. 67	8. 65	13. 1	17. 6	26. 5	35. 6	44. 7	53. 9	63. 0	72. 3
1. 67	----	----	6. 73	8. 73	13. 2	17. 7	26. 8	35. 9	45. 1	54. 4	63. 6	73. 0
1. 68	----	----	6. 79	8. 81	13. 3	17. 9	27. 0	36. 3	45. 6	54. 9	64. 3	73. 7
1. 69	----	----	6. 86	8. 89	13. 5	18. 0	27. 3	36. 6	46. 0	55. 4	64. 9	74. 4
1. 70	----	----	6. 92	8. 97	13. 6	18. 2	27. 6	37. 0	46. 4	56. 0	65. 5	75. 1
1. 71	----	----	6. 98	9. 05	13. 7	18. 4	27. 8	37. 3	46. 9	56. 5	66. 1	75. 8
1. 72	----	----	7. 04	9. 13	13. 8	18. 5	28. 1	37. 7	47. 3	57. 0	66. 7	76. 5
1. 73	----	----	7. 11	9. 21	13. 9	18. 7	28. 3	38. 0	47. 7	57. 5	67. 3	77. 2
1. 74	----	----	7. 17	9. 29	14. 1	18. 9	28. 6	38. 3	48. 2	58. 1	68. 0	77. 9
1. 75	----	----	7. 23	9. 38	14. 2	19. 0	28. 8	38. 7	48. 6	58. 6	68. 6	78. 7
1. 76	----	----	7. 29	9. 46	14. 3	19. 2	29. 1	39. 0	49. 1	59. 1	69. 2	79. 4
1. 77	----	----	7. 36	9. 54	14. 4	19. 4	29. 3	39. 4	49. 5	59. 7	69. 9	80. 1
1. 78	----	----	7. 42	9. 62	14. 6	19. 6	29. 6	39. 7	49. 9	60. 2	70. 5	80. 8
1. 79	----	----	7. 48	9. 70	14. 7	19. 7	29. 9	40. 1	50. 4	60. 7	71. 1	81. 6

1.80	----	----	7.54	9.79	14.8	19.9	30.1	40.5	50.8	61.3	71.8	82.3
1.81	----	----	7.61	9.87	15.0	20.1	30.4	40.8	51.3	61.8	72.4	83.0
1.82	----	----	7.68	9.95	15.1	20.2	30.7	41.2	51.7	62.4	73.0	83.8
1.83	----	----	7.74	10.0	15.2	20.4	30.9	41.5	52.2	62.9	73.7	84.5
1.84	----	----	7.81	10.1	15.3	20.6	31.2	41.9	52.6	63.5	74.3	85.3
1.85	----	----	7.87	10.2	15.5	20.8	31.5	42.2	53.1	64.0	75.0	86.0
1.86	----	----	7.94	10.3	15.6	20.9	31.7	42.6	53.6	64.6	75.6	86.8
1.87	----	----	8.00	10.4	15.7	21.1	32.0	43.0	54.0	65.1	76.3	87.5
1.88	----	----	8.06	10.5	15.8	21.3	32.3	43.3	54.5	65.7	76.9	88.3
1.89	----	----	8.13	10.5	16.0	21.5	32.5	43.7	54.9	66.3	77.6	89.0
1.90	----	----	8.20	10.6	16.1	21.6	32.8	44.1	55.4	66.8	78.2	89.8
1.91	----	----	8.26	10.7	16.2	21.8	33.1	44.4	55.9	67.4	78.9	90.5
1.92	----	----	8.33	10.8	16.4	22.0	33.3	44.8	56.3	67.9	79.6	91.3
1.93	----	----	8.40	10.9	16.5	22.2	33.6	45.2	56.8	68.5	80.2	92.1
1.94	----	----	8.46	11.0	16.6	22.4	33.9	45.5	57.3	69.1	80.9	92.8
1.95	----	----	8.52	11.1	16.7	22.5	34.1	45.9	57.7	69.6	81.6	93.6
1.96	----	----	8.59	11.1	16.9	22.7	34.4	46.3	58.2	70.2	82.2	94.4
1.97	----	----	8.66	11.2	17.0	22.9	34.7	46.6	58.7	70.8	82.9	95.1
1.98	----	----	8.73	11.3	17.2	23.1	35.0	47.0	59.1	71.4	83.6	95.9
1.99	----	----	8.80	11.4	17.3	23.2	35.3	47.4	59.6	71.9	84.3	96.7
2.00	----	----	8.87	11.5	17.4	23.4	35.5	47.8	60.1	72.5	84.9	97.5
2.01	----	----	----	11.6	17.6	23.6	35.8	48.1	60.6	73.1	85.6	98.3
2.02	----	----	----	11.7	17.7	23.8	36.1	48.5	61.0	73.7	86.3	99.1
2.03	----	----	----	11.8	17.8	24.0	36.4	48.9	61.5	74.2	87.0	99.8
2.04	----	----	----	11.8	18.0	24.2	36.7	49.3	62.0	74.8	87.7	100.6
2.05	----	----	----	11.9	18.1	24.3	36.9	49.7	62.5	75.4	88.4	101.4
2.06	----	----	----	12.0	18.2	24.5	37.2	50.1	63.0	76.0	89.1	102.2
2.07	----	----	----	12.1	18.4	24.7	37.5	50.4	63.5	76.6	89.8	103.0
2.08	----	----	----	12.2	18.5	24.9	37.8	50.8	63.9	77.2	90.4	103.8
2.09	----	----	----	12.3	18.7	25.1	38.1	51.2	64.4	77.8	91.1	104.6

TABLE 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

[Letters, H_a, and W, refer to figure 2. To convert decimal fractions of a foot to inches and fractions, see corresponding units in table 2]

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—											
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
	Second-feet	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
2.10	----	----	----	12.4	18.8	25.3	38.4	51.6	64.9	78.4	91.8	105.4
2.11	----	----	----	12.5	18.9	25.5	38.6	52.0	65.4	79.0	92.5	106.2
2.12	----	----	----	12.6	19.0	25.6	38.9	52.4	65.9	79.6	93.3	107.0
2.13	----	----	----	12.6	19.2	25.8	39.2	52.8	66.4	80.2	94.0	107.9
2.14	----	----	----	12.7	19.3	26.0	39.5	53.2	66.9	80.8	94.7	108.7
2.15	----	----	----	12.8	19.5	26.2	39.8	53.5	67.4	81.4	95.4	109.5
2.16	----	----	----	12.9	19.6	26.4	40.1	53.9	67.9	82.0	96.1	110.3
2.17	----	----	----	13.0	19.7	26.6	40.4	54.3	68.4	82.6	96.8	111.1
2.18	----	----	----	13.1	19.9	26.8	40.7	54.7	68.9	83.2	97.5	111.9
2.19	----	----	----	13.2	20.0	27.0	41.0	55.1	69.4	83.8	98.2	112.8
2.20	----	----	----	13.3	20.2	27.2	41.3	55.5	69.9	84.4	98.9	113.6
2.21	----	----	----	13.4	20.3	27.3	41.5	55.9	70.4	85.0	99.7	114.4
2.22	----	----	----	13.5	20.5	27.5	41.8	56.3	70.9	85.6	100.4	115.3
2.23	----	----	----	13.6	20.6	27.7	42.1	56.7	71.4	86.3	101.1	116.1
2.24	----	----	----	13.7	20.7	27.9	42.4	57.1	71.9	86.9	101.8	116.9
2.25	----	----	----	13.7	20.9	28.1	42.7	57.5	72.4	87.5	102.6	117.8
2.26	----	----	----	13.8	21.0	28.3	43.0	57.9	72.9	88.1	103.3	118.6
2.27	----	----	----	13.9	21.2	28.5	43.3	58.3	73.5	88.7	104.0	119.5
2.28	----	----	----	14.0	21.3	28.7	43.6	58.7	74.0	89.4	104.8	120.3
2.29	----	----	----	14.1	21.4	28.9	43.9	59.2	74.5	90.0	105.5	121.2

2.30	----	----	----	14.2	21.6	29.1	44.2	59.6	75.0	90.6	106.2	122.0
2.31	----	----	----	14.3	21.7	29.3	44.5	60.0	75.5	91.2	107.0	122.9
2.32	----	----	----	14.4	21.9	29.5	44.8	60.4	76.1	91.9	107.7	123.7
2.33	----	----	----	14.5	22.0	29.7	45.1	60.8	76.6	92.5	108.5	124.6
2.34	----	----	----	14.6	22.2	29.9	45.4	61.2	77.1	93.1	109.2	125.4
2.35	----	----	----	14.7	22.4	30.1	45.7	61.6	77.6	93.8	110.0	126.3
2.36	----	----	----	14.8	22.5	30.3	46.0	62.0	78.1	94.4	110.7	127.2
2.37	----	----	----	14.9	22.6	30.5	46.4	62.4	78.7	95.1	111.5	128.0
2.38	----	----	----	15.0	22.8	30.7	46.7	62.9	79.2	95.7	112.2	128.9
2.39	----	----	----	15.1	22.9	30.9	47.0	63.3	79.7	96.3	113.0	129.8
2.40	----	----	----	15.2	23.0	31.1	47.3	63.7	80.3	97.0	113.7	130.7
2.41	----	----	----	15.3	23.2	31.3	47.6	64.1	80.8	97.6	114.5	131.5
2.42	----	----	----	15.4	23.3	31.5	47.9	64.5	81.3	98.3	115.3	132.4
2.43	----	----	----	15.5	23.5	31.7	48.2	65.0	81.8	98.9	116.0	133.3
2.44	----	----	----	15.6	23.7	31.9	48.5	65.4	82.4	99.6	116.8	134.2
2.45	----	----	----	15.6	23.8	32.1	48.8	65.8	82.9	100.2	117.6	135.1
2.46	----	----	----	15.7	23.9	32.3	49.1	66.2	83.5	100.9	118.3	135.9
2.47	----	----	----	15.9	24.1	32.5	49.5	66.7	84.0	101.5	119.1	136.8
2.48	----	----	----	15.9	24.2	32.7	49.8	67.1	84.5	102.2	119.9	137.7
2.49	----	----	----	16.0	24.4	32.9	50.1	67.5	85.1	102.8	120.6	138.6
2.50	----	----	----	16.1	24.6	33.1	50.4	67.9	85.6	103.5	121.4	139.5

head and the size of flume in use. If the ratio of the two heads exceeds these limits, the flow is submerged and the rate of discharge is reduced. The ratio H_b to H_a is found by dividing the value of the depth or head at H_b by the depth measured at H_a. Table 6 gives the rates of discharge in second-feet through this flume for sizes ranging from a 3-inch throat width to that of 8 feet. The 3-inch flume is intended for the accurate measurement of small flows down to an approximate minimum of 0.03 second-foot.

To illustrate the determination of the degree of submergence and rate of discharge, let it be assumed that for a 2-foot flume the H_a head is 2.13 feet and the H_b head is 1.30 feet. The ratio H_b to H_a is 1.30 divided by 2.13 or 0.61. Since this value is less than 0.7, which is the limiting degree of submergence before the free-flow rate of discharge is affected, the discharge as shown in table 6 for H_a=2.13 feet is 25.8 second-feet.

Submerged Flow

When the ratio of the two heads, H_b and H_a, exceeds 0.7 for flumes of throat widths 1 to 8 feet, it becomes necessary to apply a negative correction to the free-flow discharge, in order to determine the rate of submerged flow. When the ratio exceeds 0.6 for flumes having throat widths of less than 1 foot, the submerged flow will be as shown in figures 3, 4, and 5. The computed submerged flow through the 1- to 8-foot flumes is determined by use of the correction diagram, figure 6. This diagram is for a 1-foot flume, and is made applicable to the larger flumes by multiplying the correction for the 1-foot flume by the factor given below, for the particular size of flume in use; and this result is then subtracted from the free-flow discharge for the particular H_a head. The factors necessary in making this computation are shown in the accompanying tabulation.

Size of flume W (feet)	*Multiplying factor, M*
1	1.0
1.5	1.4
2	1.8
3	2.4
4	3.1
5	3.7
6	4.3
7	4.9
8	5.4

The following examples illustrate the method of computing submerged-flow discharge through the Parshall measuring flume by use of the correction diagram:

What will be the discharge through a 1-foot flume with an H_a head of 1.60 feet and H_b of 1.41 feet? The ratio of 1.41/1.60 is approximately 0.88, or 88 percent. At the left margin of the diagram (figure 6) enter at the value 1.60 and then follow horizontally to the right until intersecting the percentage of submergence line 88. Now follow vertically downward to the base of the diagram and observe the correction value of 1.80 second-feet, which is the amount to be subtracted from the free-flow discharge as given in table 6, for H_a=1.60 feet. Therefore, the submerged-flow discharge will be 8.18−1.80, or 6.38 second-feet.

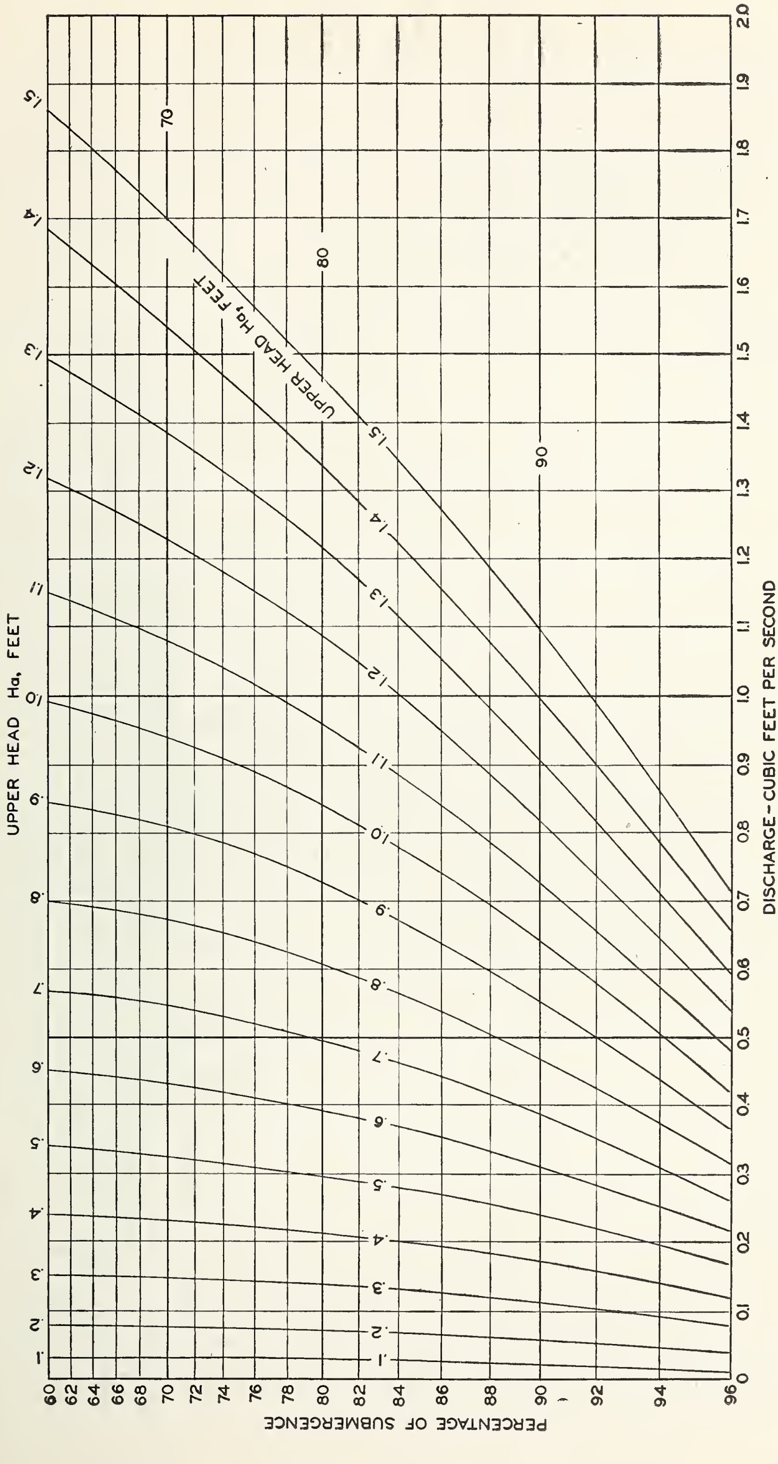

FIGURE 3.—Diagram showing the rate of submerged flow, in cubic feet per second, through a 3-inch Parshall measuring flume.

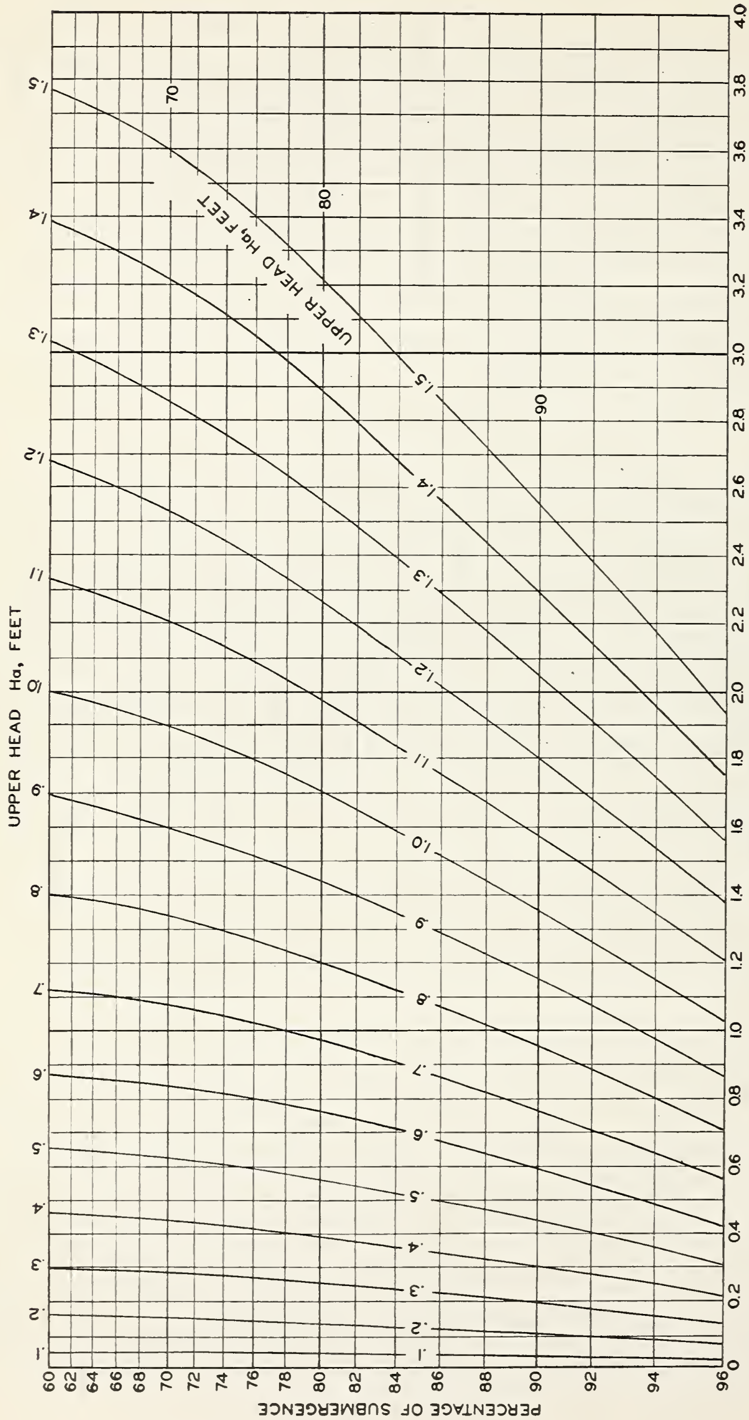

FIGURE 4.—Diagram showing the rate of submerged flow, in cubic feet per second, through a 6-inch Parshall measuring flume.

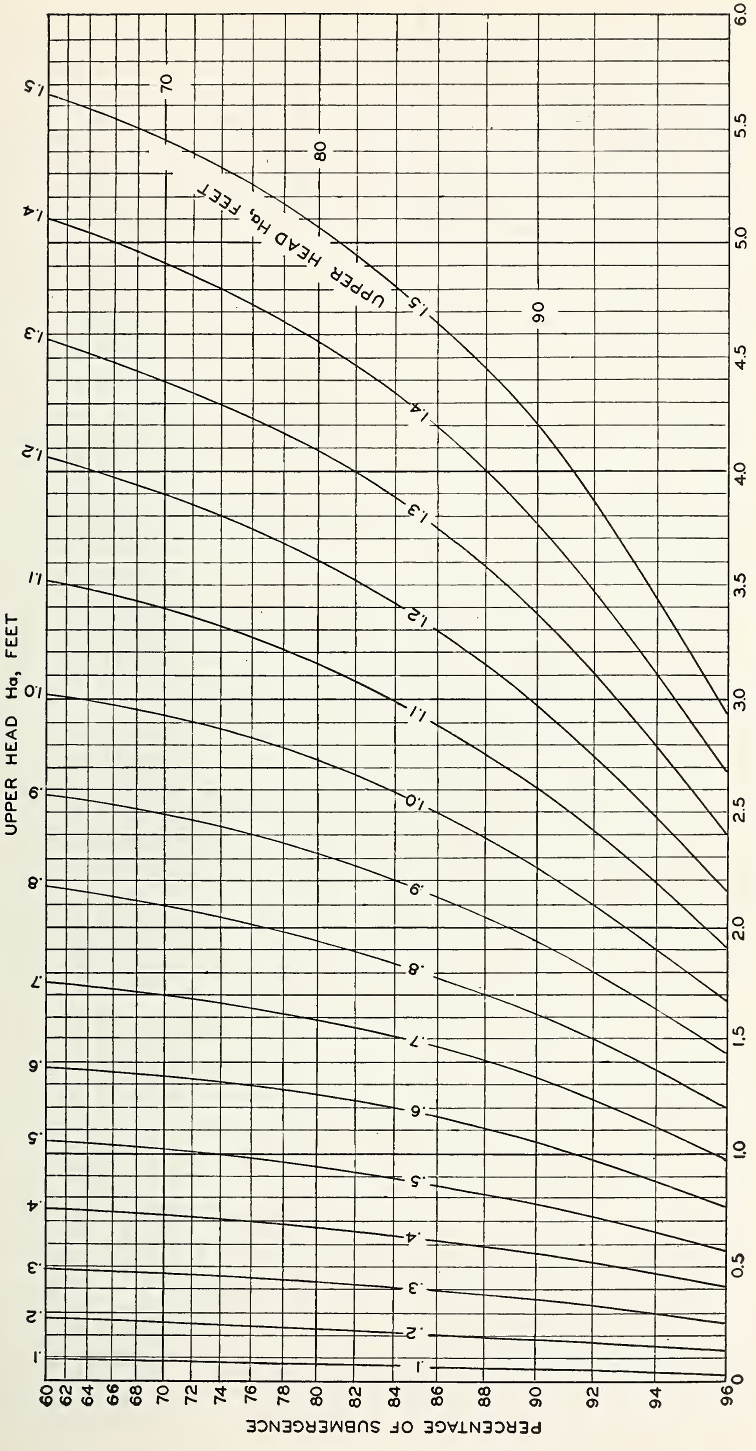

FIGURE 5.—Diagram showing the rate of submerged flow, in cubic feet per second, through a 9-inch Parshall measuring flume.

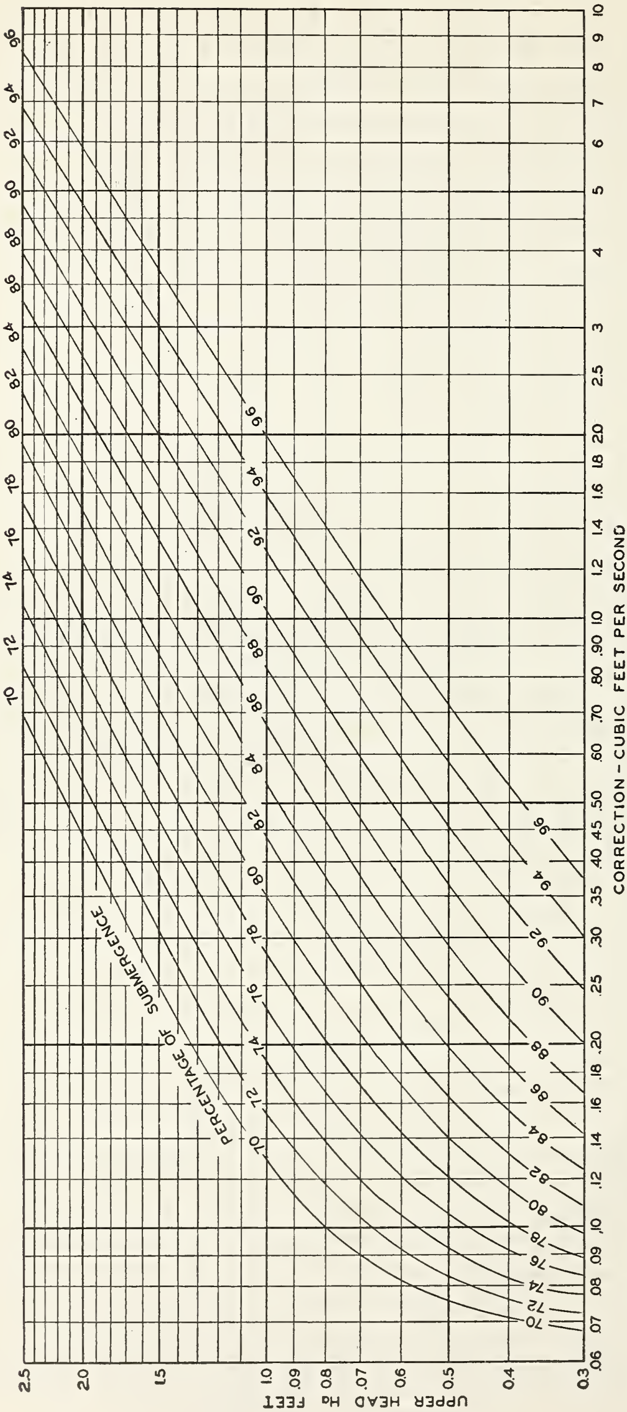

FIGURE 6.—Diagram for computing the rate of submerged flow, in cubic feet per second, through a 1-foot Parshall measuring flume.

As another example, let it be assumed that the discharge to be ascertained is for a submerged-flow through a 3-foot flume having H_a at 2.10 feet and H_b at 2.00 feet. Here the ratio 2.00/2.10 is very closely 0.95 or 95 percent. As before, enter the diagram at the left, at the value H_a equals 2.10, and follow horizontally to the right to a point midway between the 94 and 96 submergence lines. Vertically below this point, on the base of the diagram, is found the correction 5.75 second-feet. This is the amount of correction for a 1-foot flume. However, since the 3-foot flume is used it will be necessary to multiply this amount by 2.4, as given in the tabulation shown above, to obtain the full correction, which for a flume of this size is 5.75 by 2.4 or 13.8 second-feet. From table 6 the free-flow discharge through a 3-foot flume for an H_a head of 2.10 feet is found to be 38.4 second-feet, and the submerged flow is therefore 38.4—13.8 or 24.6 second-feet.

The submerged flow through a 6-foot flume with H_a at 1.79 feet and H_b at 1.65 feet is found by use of the correction diagram to be 46.7 second-feet.

For the small flumes (i. e., those having less than 1-foot throat-widths) the submerged flow is determined direct from diagram figure 3, 4, or 5, according to which size of flume is used. For example: What is the discharge through a 3-inch flume with an H_a head of 1.32 feet and H_b of 1.20 feet? In this case the ratio of the two heads is 91 percent. Referring to figure 3, it will be noted that at the left-hand margin of the diagram the degree of submergence is shown. At the submergence of 91 percent, estimated as being midway between 90 and 92, move to the right to the upper head H_a of 1.32, which would be one-fifth the distance between the H_a curved lines 1.3 and 1.4 at this particular submergence. Vertically beneath this point, on the base of the diagram, will be found the submerged rate of flow in cubic feet per second, or 0.88 second-foot.

As another example: What is the submerged flow through the 9-inch flume with an H_a head of 1.40 feet and H_b of 1.20 feet? The ratio here is found to be approximately 86 percent. In figure 5, follow to the right on submergence line 86 to the intersection with the upper head H_a curve 1.4. Vertically below it will be found the submerged flow of 4.19 second-feet.

Size and Setting of Flume

To operate the Parshall measuring flume as a single head device or at a predetermined degree of submergence for a particular rate of flow, it will be necessary to determine quite accurately the elevation of the crest with reference to the bed of the channel. Where sufficient fall is available this setting may be determined with little difficulty, but if the fall or grade of the channel is slight, care must be taken in fixing the height of the crest so that, if possible, the degree of submergence shall not exceed the limits of free-flow operation, as explained on page 34. If conditions will not permit free-flow operation, the setting should be so made that minimum submergence will exist.

It has been found from field experience in the use of small flumes for measuring farm deliveries from canal that on the average about 75 percent of the flume installations would operate free-flow and 15 to 20 percent at moderate to high submergence; the remainder would be in laterals of grades so flat as to cause the degree of submergence to exceed 95 percent, which is beyond the recommended limit of practical operation. It is necessary in all cases to set the crest so that the degree of submergence shall not exceed the practical limit of about 95 percent, since the flume will not measure dependably if the submergence is greater. The elevation of the crest of the flume depends upon both the quantity of water to be measured and the size of the flume.

The selection of the location or site is sometimes important. Generally, it is best to have it conveniently near the point of diversion or regulating gate if conditions of operation require frequent notation of discharge. The flume should not be placed too near the headgate, as the disturbed water just downstream from the outlet may cause surging and unbalanced flow; it had best be in a straight section of the channel.

Following the selection of the site it is necessary to determine the size and proper elevation of the crest. Examples are given below to assist in the problem of size and setting of the measuring flume as covered by general field conditions usually found in irrigation practice. For example: 20 second-feet is to be measured in a channel of moderate grade where the water depth is 2.5 feet. This quantity of flow can be measured through several sizes of flume, but for the sake of economy the smallest practical size should be selected.

First, let it be assumed that a submergence of 70 percent shall not be exceeded in order that the flow may be determined by the single gage reading of H_a.

To meet these requirements three different sizes of flumes and settings will be investigated. First: For a 4-foot flume and a discharge of 20 second-feet, the H_a head is found to be 1.15 feet (table 6); For a submergence of 70 percent, the ratio of H_b gage to H_a gage is 0.7; hence H_b for this condition of flow is 0.81 foot. At 70 percent submergence, the water surface in the throat at the H_b gage is essentially level with that at the lower end of the flume. Under this condition of flow, the water depth just below the structure will be approximately the same as before the flume was installed; that is, 2.5 feet. In figure

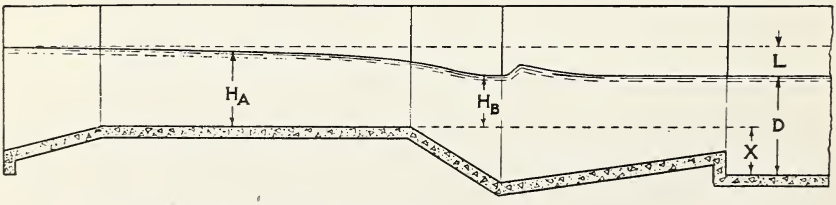

FIGURE 7.—Section of a Parshall measuring flume illustrating the determination of the proper crest elevation.

7 the dimension D, represents this depth of 2.5 feet. By subtracting H_b, or 0.81 foot, from 2.5 feet, the value of X, or 1.69 feet, is obtained. This is the elevation of the crest above the bottom of the channel. For this size of flume, set with the crest at 1.69 feet above the bed of the channel, the flow of 20 second-feet will be at 70 percent submergence, and the actual loss of head or difference in elevation between

the upstream and downstream water surfaces will be 0.40 foot, as determined by figure 8. The depth of water upstream from the structure at a flow of 20 second-feet will therefore be 2.90 feet. It will be necessary to examine the freeboard of the channel, as well as the effect of the rise of the water surface upon the flow through the headgate, in deciding which size of flume is the most practical.

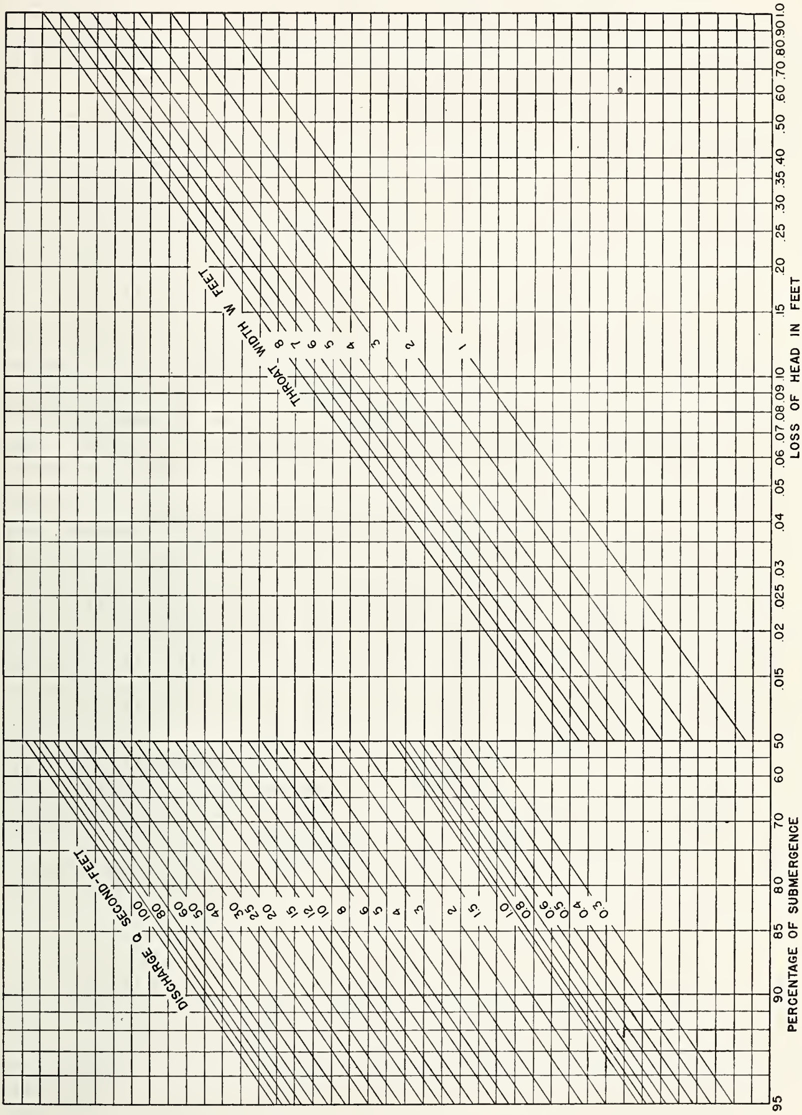

FIGURE 8.—Diagram for determining the loss of head through the Parshall measuring flume, 1- to 8-foot sizes.

Second: For a 3-foot flume and discharge of 20 second-feet, the H_a head is found to be 1.39 feet (table 6). Again for a submergence of 70 percent, the ratio of H_b to H_a is 0.7; hence the H_b for this condition of flow is 0.97. By reference to figure 7, the value of X, or the elevation of the crest above the bottom of the channel, is found to be

1.53 feet, and the actual loss of head through the flume (figure 8) is found to be 0.48 foot. The depth of water upstream for this size of flume will now be 2.98 feet.

Next consider a 2-foot flume: As before, find the H_a head in table 6 for a free flow of 20 second-feet. For the 2-foot flume this head is 1.81 feet. At a submergence of 70 percent, the value of H_b is 1.27 feet. By again referring to figure 7, the value of X or the elevation of the crest above the bed of channel is determined to be 2.50—1.27, or 1.23 feet. For this size of flume discharging 20 second-feet at a submergence of 70 percent, the actual loss of head (figure 8) is 0.61 foot and the depth of water upstream is 3.11 feet.

If it is found that the banks of the channel and entrance conditions through the headgates are satisfactory, the 2-foot flume will be most economical because of its small dimensions; however, when width of channel is considered the final selection may favor the 3- or 4-foot flume, because moderate to long wing walls may be required. Usually, the width of the throat of the flume will be from one-third to one-half the width of the channel.

In the above analysis of the three sizes of flumes investigated the fact is to be observed that the actual increase or rise in the depth of water upstream from the structure is considerably less than the elevation of the crest above the bottom of the channel. For the 4-foot flume the crest is 1.69 feet above the bed of channel and the rise in water upstream will be only 0.40 feet, or about 24 percent; for the 3-foot flume the rise is about 31 percent; for the 2-foot flume it is about 50 percent.

This analysis further shows that as the size of flume is decreased, the elevation of the crest becomes less, and the depth of water upstream from the structure becomes greater for similar rates of discharge and like degrees of submergence. It is usually the better practice to set the flume high rather than low, to provide a margin of safety for variations of the water surface downstream. In irrigation channels, especially those with earth banks and bottom, deposits of sand or silt may change the downstream flow conditions, and weeds, willows, or moss may likewise affect the degree of submergence.

If it is found impractical to set the flume to operate under a free-flow condition, because of insufficient grade or other limiting conditions, it becomes necessary to use both the H_a and H_b gages to determine the discharge, as previously explained. The flume may be placed so as to operate at any degree of submergence for any particular rate of flow.

CONSTRUCTION

The Parshall measuring flume may be constructed of timber, concrete or (in the smaller sizes) sheet metal. The dimensions for the various sizes are given in table 5. The several columns in this table headed by capital letters refer to the corresponding dimensions shown in figure 2. In the construction of this flume it is necessary to build to exact dimensions, especially with respect to the converging and throat sections. The two gage points, H_a and H_b, must be referenced with exactness to the distances given in table 5.

For flumes made of lumber, covering the sizes described in this bulletin, it is recommended that the sills and posts be of ample dimensions with substantial cross ties spanning the top. The 1- to 4-foot structures should have 4- by 4-inch sills and posts, floor and walls of 2-inch surfaced planking and 2- by 6-inch cross ties; for the 5- to 8-foot sized flumes, 4- by 6-inch sills and posts and 3-inch surfaced planking for the floor and walls. Materials pretreated with appropriate preservatives will lengthen greatly the life of the structure. The bottom wall planks should be set before the floor is laid. This scheme of construction will prevent the side walls from crowding or bulging inward at the bottom, which would otherwise alter the inside dimensions. It is recommended that a space of 1/8 to 1/4 inch be left between the floor and wall planks when placed, to allow for swelling of the wood.

It is essential that the crest be straight and level, and that the floor of the converging section be level in both directions. An angle-iron crest, 1½ by 1½ by $\frac{3}{16}$ inch, is strongly recommended, to insure a definite surface and true edge. This metal piece should be gained in to set flush with the floor surface and be held in place by heavy countersunk screws.

Suitable wing walls should be at both ends of the structure. As a means of improving the flow conditions within the converging section of the flume, curved wing walls at a suitable radius, as shown in figure 2, are recommended in preference to straight walls set at 45 degrees. To accomplish this curved transition, for a timber structure, it is suggested that a post be set firmly in a vertical position at a point $P/2$ out from the axis of the flume and M distance upstream from the front end of the converging section. Either two or three flat band-irons of suitable length bent to the proper radius (table 5) should be provided, with one end bolted to the inside face of the wall and the other to the vertical post. For a wall 3 feet high, three band-irons, 1 by 1/4 inch, are needed, one at the floor line, one at the top, and the other approximately midway between them. Pieces of 2 by 4's cut to the proper length and set vertical behind the band-irons with tops at the elevation of the wall, will provide an excellent curved transition. The backfill will hold the pieces in place. A short sloping approach floor at the front end of the converging section is also desirable.

The wing walls at the downstream end of the flume should extend back far enough into the banks of the channel to give protection against caving of the backfill. These wings may be placed at right angles to the axis of the structure. A cut-off wall of reasonable depth should extend across the channel as a part of the wing walls and the downstream end of the diverging section. If the material composing the bed and banks of the channel is soft, either a stone or wooden apron should be provided at the downstream end of the structure to prevent undue erosion.

For permanency, monolithic reinforced concrete flumes are built in all sizes ranging from a throat width of 3 inches up to large structures having a throat width of 40 feet. Such structures are little subject to damage by expansion or contraction, thus insuring uniformity of operation.

This type of measuring device may be constructed of sheet metal for sizes ranging from 3-inch to 10-foot throat widths. Metal flumes have proved very satisfactory, but the cost somewhat exceeds that of either wood or concrete. The metal flume has advantage in being portable; it can readily be reset and readjusted if improperly placed at the start, and is relatively long-lived and immune from fire hazards such as are occasioned by ditch-cleaning operations. Factory-made flumes of this type should insure accuracy of dimensions and uniform construction.

Figure 9 is a practical design of a metal flume.

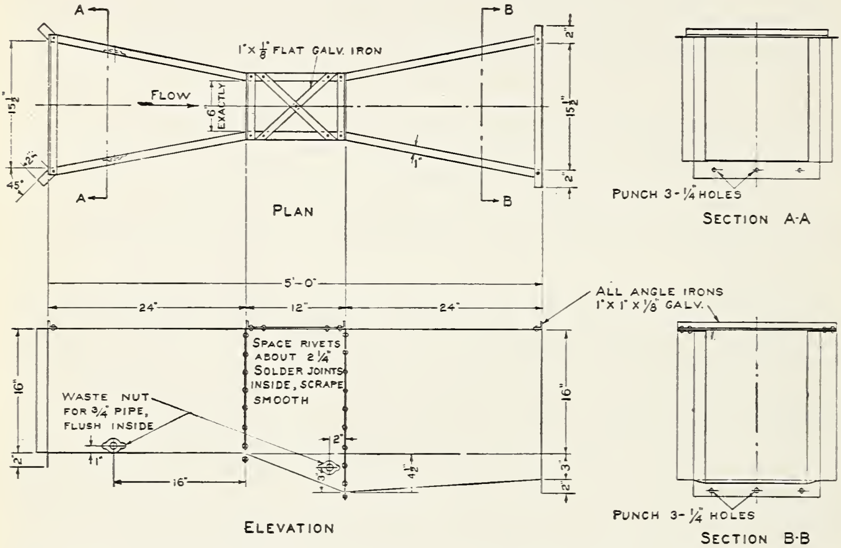

FIGURE 9.—Plan and elevation of a 6-inch sheet-metal Parshall measuring flume.

Flumes using transite board or similar material in the construction are being prefabricated at Bogota, Colombia, South America.

Portable Form for Casting Small Reinforced Concrete Parshall Measuring Flumes

As a means of promoting the economical construction of the smaller size Parshall measuring flumes, a portable knock-down form has been perfected for casting 3-, 6-, or 9-inch structures. Where several small flumes of the same size are to be used in distributing water to the farmer, in amounts ranging from about 0.10 to 6 or 8 second-feet, it has been found that such a form is advantageous from the standpoint of unit cost per structure. The form has the further advantage that the finished structure will be true to dimension, uniform in design, and of workmanlike appearance.

The design of this form,[2] which is shown in complete detail for a 9-inch Parshall flume in figures 10, 11, 12, 13, and 14, is intended to include no single part or section of such weight or dimension as would cause inconvenience or difficulty in field assembly. The form consists of two parts, right and left sections, for casting the walls. The parts

[2] To build the portable form for other sizes of the Parshall measuring flume refer to table 5 for the general dimensions; other details are to be incorporated accordingly.

of the form are tied together across the top with slotted angle irons fitted exactly to stud bolts, to insure accuracy of spacing. A long dowel pin, vertical at the throat, spaces the forms to provide the exact dimension or length of crest. At the upstream end are mounted curved sheet-metal wings, which are detachable and secured in position by notched inserts at the bottom and a spreader bar at the top. A single piece joins the two halves of the form at the downstream end and provides the casting surface for the faces of the wing walls and the end of the structure. The upstream wings and downstream end-panel section are attached to the ends of the outside forms by means of slotted metal clips which provide accurate spacing and rapid assembly. These clips support the sheet-metal strips that cast the ends of the walls of the structure.

Short pieces of 1- by 1- by ⅛-inch angle iron, cut to the proper lengths and supported by slotted holes through the outside forms, fix the exact elevation of the floor of the converging section and the throat floor. These angle irons are cast into the structure, and when the floors are being finished they serve as guides in striking a true surface. The angle at the toe of the throat floor and the edge of the downstream panel provides for striking the floor of the diverging section. At the exact location of the H_a and H_b gage points, ¼-inch holes are drilled to support tapered metal plugs which are cast in the wall of the structure. After the forms are removed, a slight tap with a hammer releases the plugs and provides a 1¼-inch hole for the tubes to the stilling wells (see description of wells, p. 56).

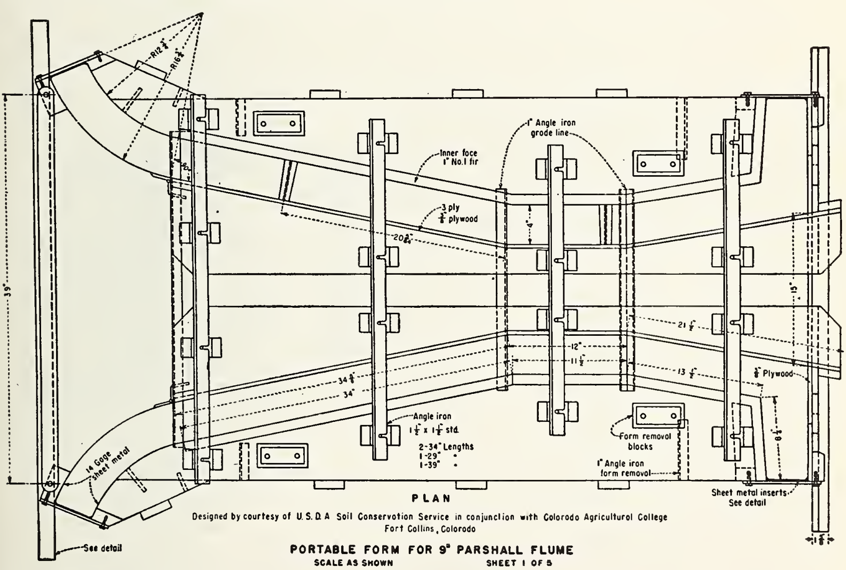

FIGURE 10.—Plan of portable form for casting a monolithic reinforced concrete 9-inch Parshall measuring flume, with walls and floor of 4-inch thickness.

The form is fabricated of well-seasoned lumber. The main framing is straight-grained 1-inch material to which is attached ⅜-inch, 3-ply waterproof board for casting the inside wall surfaces and ¾-inch common lumber for the outside wall surfaces.

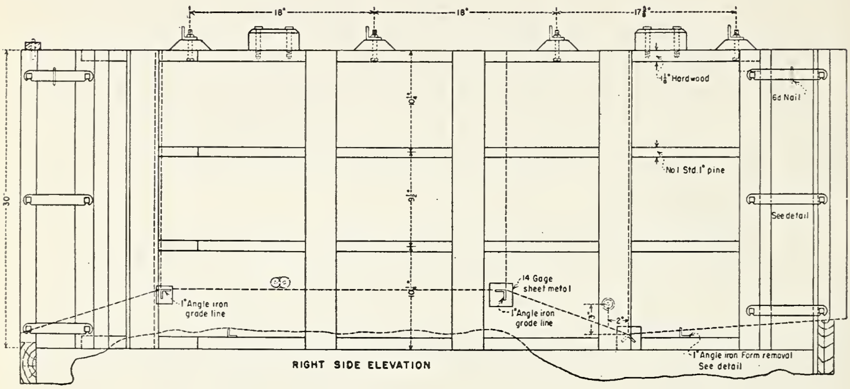

FIGURE 11.—Side elevation of portable form for casting 9-inch Parshall measuring flume.

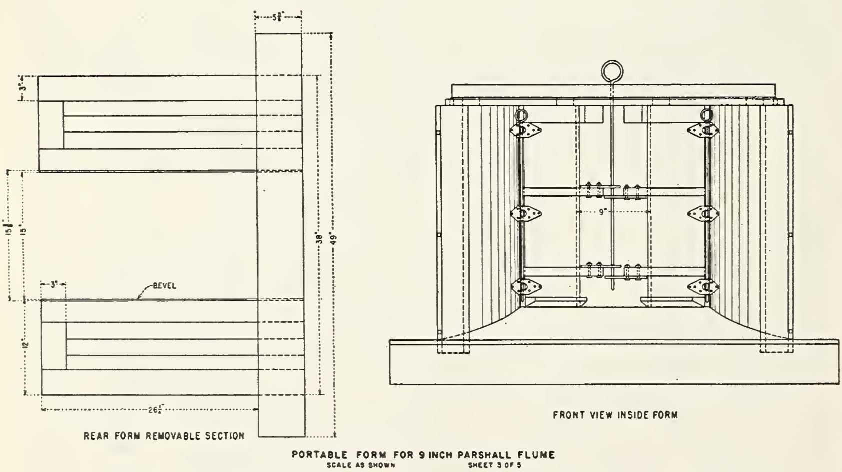

FIGURE 12.—End elevations of portable form for casting 9-inch Parshall measuring flume.

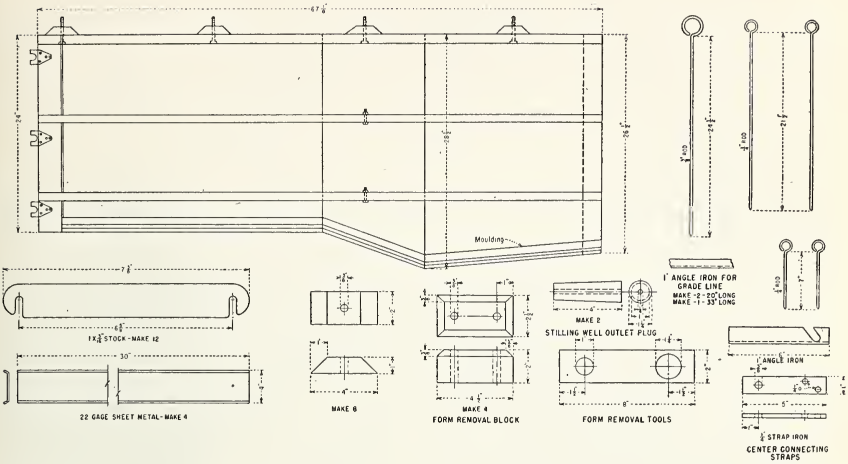

FIGURE 13.—Side elevation of inside form of portable form for casting 9-inch Parshall measuring flume. Detail of parts and accessories with dimensions.

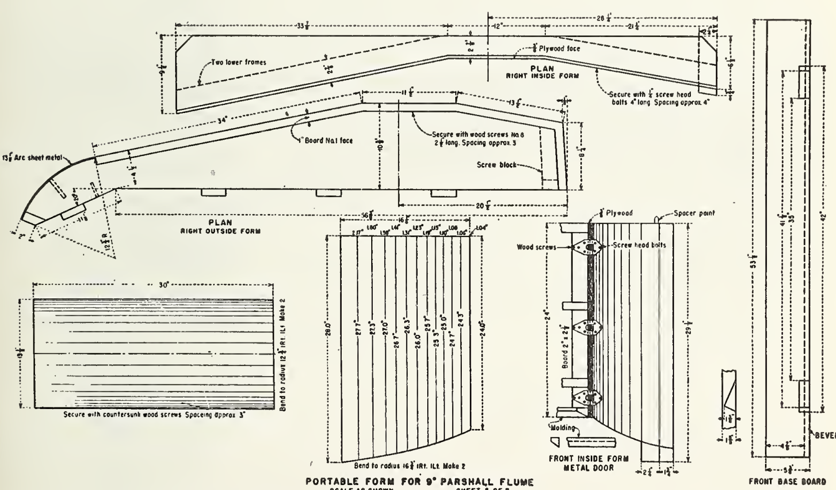

FIGURE 14.—Plan, top of inside and outside forms, detail of curved wing door and front baseboard, of portable form for casting 9-inch Parshall measuring flume.

Some of the experimental forms had transite board or 10-gage metal sheet for casting the inside faces of the flume walls. For the wooden forms, all the principal joints are made up with a good grade of waterproof glue. The assembled parts are secured with substantial countersunk flathead wood screws. On the top face of the forms (not shown in the plans) are fixed strips of 1¼- by ⅛-inch strap iron, with the edges agreeing with the inner faces of the casting surfaces. This metal edging serves as a protection against injury from shoveling the concrete into the form, also providing a smooth continuous surface for striking off the top of the walls after the form is filled.

The approximate weight of this type of portable form for a 6- or 9-inch flume, complete with accessories, is about 250 pounds. At present rates (1948) for materials and labor, such a form would cost at least $350.

Portable Sheet-Metal Construction Form

The portable form may be made of sheet metal as shown in figure 15. This 3-inch form is constructed of 16-gage galvanized iron, ribbed with ¾-inch angle iron. Long straight metal dowel pins tie the inner and outer sections together at the ends, and at the throat the form is also held in place by means of a long pin, as shown. The ties spanning the top assure the correct spacing, and are set about 1 inch above the edge of the form to permit finishing the top of the walls. Wedge boards, not shown, support the inner sections of the form to provide a true plane surface of the inside face. The short dowel pins for the H_a and H_b taper plugs are clearly shown in the foreground. This all-

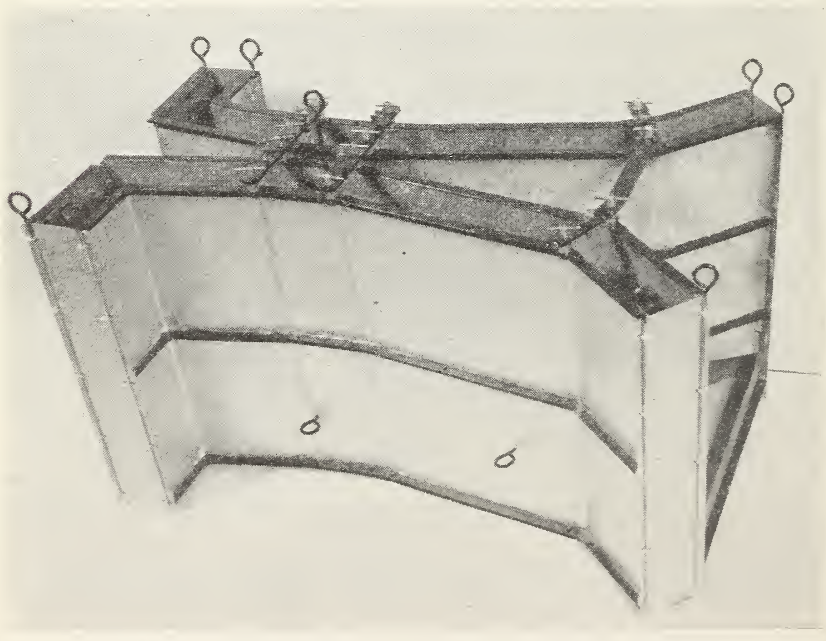

Figure 15.—Metal portable form for casting monolithic reinforced concrete 3-inch Parshall measuring flume, with walls and floor of 3-inch thickness.

metal form weighs about 100 pounds and has been used to cast some 150 structures without appreciable wear.

Constructing Small Concrete Parshall Measuring Flumes by Use of Portable Form

The most practical method of building small concrete flumes is by use of the portable knock-down form which is easily assembled and placed in position ready for casting the structure.

After the site has been selected, size of flume determined, and the

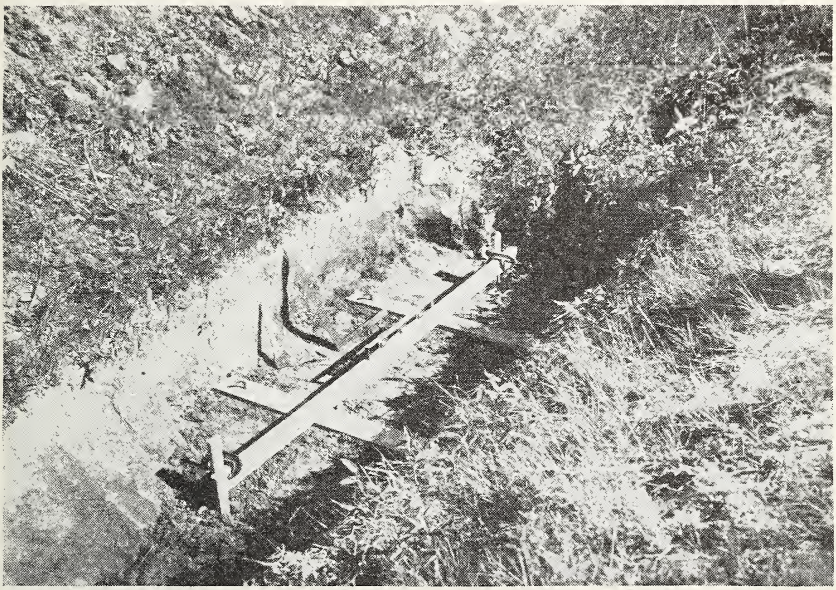

Figure 16.—View showing excavation, 2- by 4-inch guide piece, and baseboards with metal pins that accurately space the setting of the outside forms for the 9-inch flume.

grade stake set, the excavation is made to the required width (at least 1½ feet oversize to provide ample space for erecting the form) and to a depth 6 inches below the elevation marked on the grade stake with bottom of pit level in both directions.

After the excavation has been prepared a second stake should be driven in the bed of the channel downstream a little short of 10 feet, at a point where the grade stake and this point will fix the axis of the structure. A piece of 2-by-4 is then fixed to the stakes by "C" clamps and leveled to position with the top edge in line with top or marked elevation of the upstream stake (fig. 16). After this guide piece has been set the two boards of 1- by 6-inch common lumber cut to a length of 47 inches are properly spaced at 45 inches for a 9-inch flume, and leveled with the top surfaces exactly 6 inches beneath the guide edge of the level 2- by 4-inch piece spanning the excavation. The form is to be erected on these pieces of board. To permit quick and accurate assembly of the form two $^{11}/_{16}$-inch holes are made, one near each end of the board, and through them are driven pointed ⅝-inch wrought-iron pins about 15 inches long with the top ends turned at right angles, as shown in figure 16, the inside edges of the holes being 39 inches apart and 19½ inches out from the center. After these pieces have been leveled and firmly bedded and adjusted transversely to position, the metal pins are driven with the tops turned as indicated and top of pin about 2 inches above the surface of the board. The 2- by 4-inch guide is now removed. The outside forms are set in place with the outside edge of the base snug against the protruding ⅝-inch metal pins (fig. 17). This arrangement provides exact spacing as well as anchorage of the base of the forms.

The forms should be kept clean, and before assembly the casting surface should be given a liberal coating of waste crankcase oil or thoroughly coated with laundry soap.

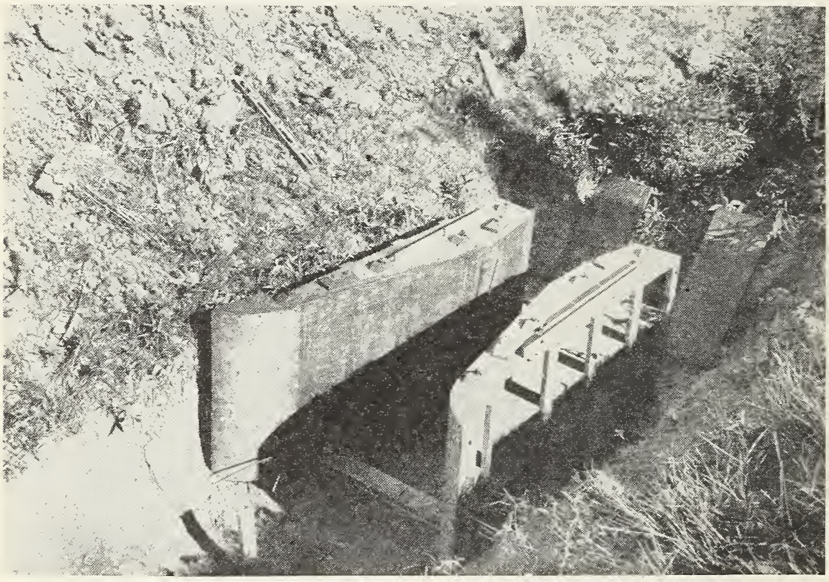

FIGURE 17.—Outside forms set in position, and downstream end panel ready for assembly after reinforcing steel has been tied in place.

The three pieces of angle iron, to serve as the floor guides, are now inserted through holes in the two outside forms as shown in the plans (fig. 11). The ⅜-inch reinforcing steel is set. There are two horizontal bars in each wall, fixed at 6 inches above the floor line of the converging section of the flume and the top bar 6 inches below top of wall. One longitudinal bar is placed in the floor, full length of structure, on the axis of the flume.

These bars are to be cut the right length and bent to conform with the angles in the walls and dip in the throat. Experience in the field indicates that the best plan for the vertical bars is to cut straight pieces about 1 foot too long and drive them downward into the bottom of the earth foundation at the proper points until the tops are at the right elevation. The vertical bars are first set in position and the horizontal bars then wired securely in place. There should be three verticals in each wall, one near the upper end of the converging section, one at the midlength of the throat and one at the end of the diverging section. Three straight transverse horizontal bars in the floor, cut to the right length, are now wired to the verticals to support the single longitudinal bar in the floor.

The end panel is now set against the downstream ends of the outside forms. Following this the inside forms are set in place, the angle-iron top cross ties are hooked over the stud bolts, and the nuts are screwed down thumb tight. The long center dowel pin is inserted to lock the two inner form sections together at the throat. The H_a taper plug is fixed between the inner and outer forms and held in place by means of the short ¼-inch dowel pin. If the flow through the flume is to be submerged the H_b plug must also be set in place.

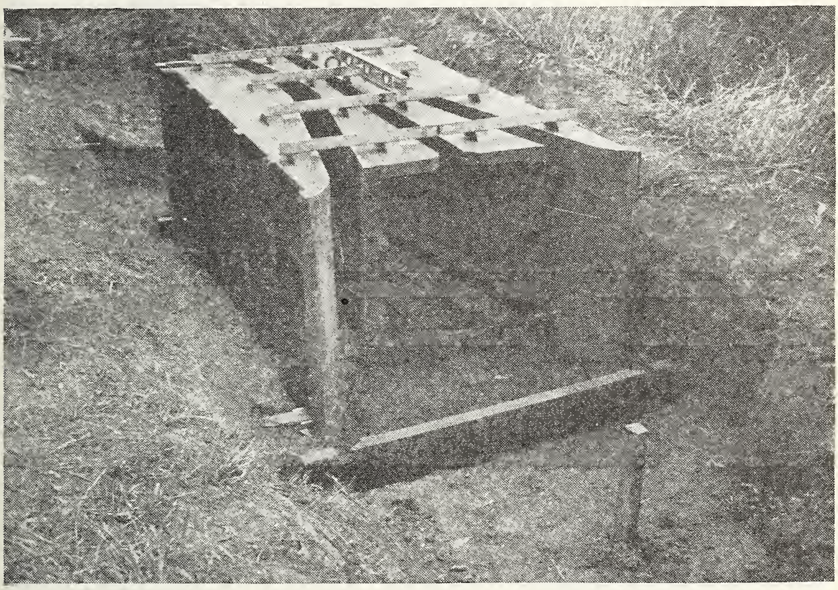

FIGURE 18.—Portable 9-inch form assembled except curved wing doors. Note the position of the 2- by 6-inch baseboards in shallow trench at front end of form.

It is important at this stage of the work to use a standard carpenter's square to test the setting of the forms by placing the square against the throat surface of the outer form and observing whether all four stud bolts are in line; otherwise, the forms may be brought to agreement by slight movement up or downstream. The downstream end panel may next be brought into position, the side clips hooked to the bolt heads, and the vertical end strips set in place. A narrow trench should be dug across the channel at the upper end of the form, of sufficient depth to allow placing the 2- by 6-inch baseboard with notches on the top edge (fig. 18). The two curved metal doors forming the entrance to the flume are now attached by the long ¼-inch dowel pins, and the baseboard is raised so that the notch will fit into the projection extending downward from the outer end of each curved door. The spacer bar fits across the top to hold the wings in position. This bar

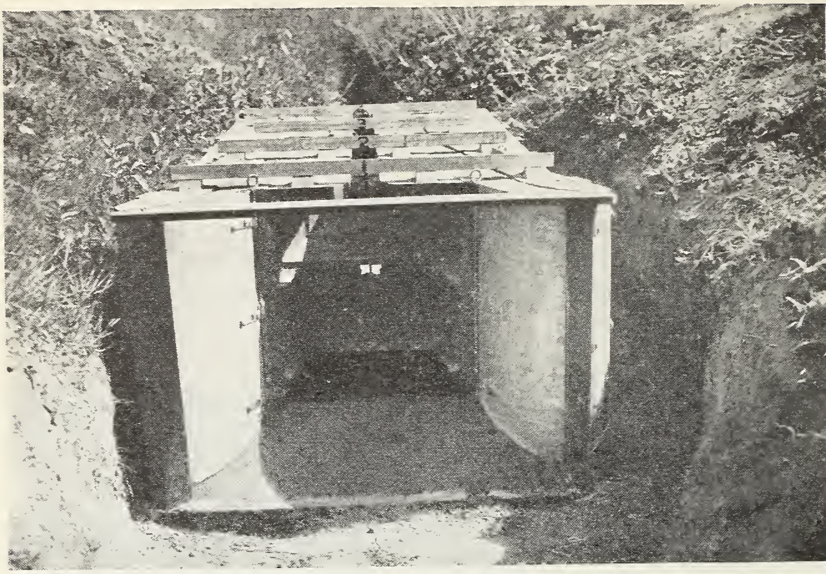

FIGURE. 19.—Nine-inch form filled with concrete and the floor of the converging section left about one-half inch below grade. The approach floor has been troweled to a finished surface. Wedge boards are in place and supported on top side of ribs of the two inside forms.

FIGURE 20.—Downstream end of concrete-filled form shown in figure 19, with wedge boards in place.

fits over short stubs at the outer end of each wing. The side clips and end strips are now placed, and the form is ready for filling with concrete. It is well, however, to check with a good carpenter's level to make sure that the form is level in both directions before actual filling is begun. The nuts holding the angle-iron cross ties should be tightened at this time.

A proportion of one part cement, and five parts of bank run (maximum 2-inch diameter) clean aggregate should give a satisfactory concrete mixture. Alkaline water should not be used. The first batch, or sufficient to fill the form to a depth of about 6 inches and for the floor should be relatively dry. The filling-in of the floor should come first, the top surface being left about one-half inch below grade for finishing after the forms are removed. After the floors have been roughly struck off, the wedge boards, shown in figures 19 and 20, are slipped into place from the two ends of the form. These tapering pieces are supported on the ribs of the inner forms and so shaped as to bear uniformly against the plywood surface, thus keeping the face of the wall true.

After the wedge boards are in place, the filling of the walls should be brought up uniformly to insure equal pressure on the forms. The mix for the side walls may be made slightly wetter and well tamped with a spading tool to dispense air pockets and work excess water up to the surface. Good spading will produce smooth, uniform wall surfaces. The angle-iron cross ties are set up about 1 inch above the forms to permit finishing of the top of walls while the concrete is still green. The sloping approach floor is the last to be finished.

Removal of the Construction Form

Under favorable weather conditions the form may be removed in 24 hours. In dismantling the form the cross ties, end clips, 3/8-inch center dowel pins, dowel pins holding the curved wing doors, taper plug pins, and the top spreader bar at front end of the forms are all removed. The vertical strips at the ends of the upstream curved wing walls are now free and should be carefully taken off. In figure 10, plan of form, "form removal blocks" are shown. These are a means of loosening the two outside forms, being substantial oak blocks bolted to the top rib of form. Tapping on these blocks with a heavy hammer will start the form. After the form shows a slight loosening the bottom should be started.

In figure 13, lower right-hand corner, are shown "center connecting straps" and "form removal tools." The former are bolted to the top side of the base rib of the form (fig. 11), and the latter hook into the notch 1-inch hole, of the former. Through the 1½-inch hole is inserted a short piece of ¾-inch common wrought-iron pipe, which serves as a lever. When the two 1- by 6-inch foundation boards are being set (page 49), the spacing should be directly beneath the center connecting straps. The over-all length of these boards—47 inches for a 9-in flume—allows 4-inch extension beyond the edge of the form. With the end of the pipe operating as a lever against the end of the foundation board, considerable outward pulling force can be exerted to start the form at the bottom. By tapping the removal block and with the pressure of the pipe lever, the form is easily withdrawn from the structure. The part of the outside form that casts the back face

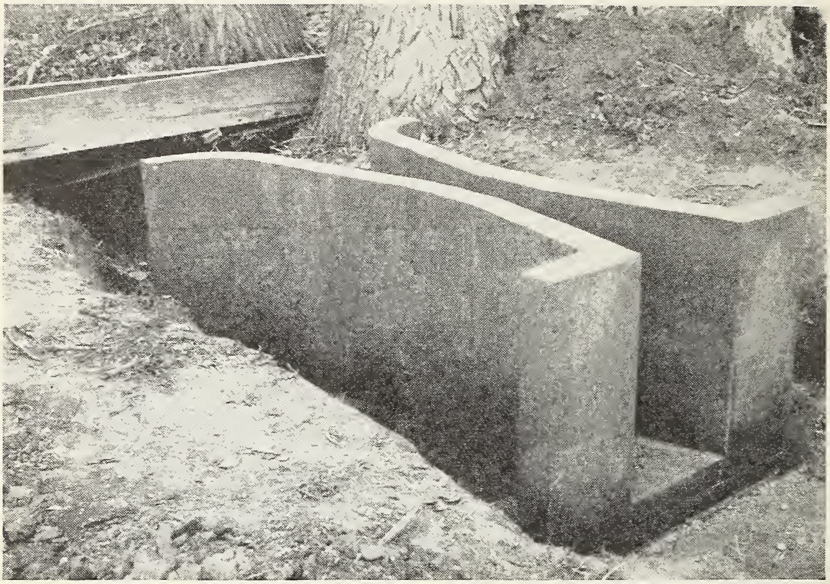

Figure 21.—General appearance of structure after forms have been removed. This flume was cast with 6-inch portable form.

Figure 22.—The 9-inch flume in action, free flow, with a discharge of 3.40 second-feet. This structure is shown in figures 19 and 20.

of the downstream wing walls is so designed as to have a taper, and once the form is loosened it should relieve any tendency to bind. The form must be moved outward uniformly; otherwise, there is some danger of cracking the wall at the downstream end of the diverging section. There should be no difficulty in removing the inside forms and the panel at the downstream end of the structure.

After the forms have been removed, the floor surfaces should be swept clean of waste concrete particles and dampened. A sand-cement mortar, proportioned one to one, should be mixed to finish the floors to a smooth, even surface, by striking off with the floor angle irons as guides. Any imperfections in the inside wall surfaces can be repaired at this time. (Before back filling see discussions of stilling wells, page 58).

Figure 21 shows a finished structure after the forms have been removed.

Figure 22 shows a 9-inch flume in action, free flow, with a discharge of 3.40 second-feet.

Figure 23 shows a 9-inch flume under submerged flow conditions. The two stilling wells are 10-inch transite pipe.

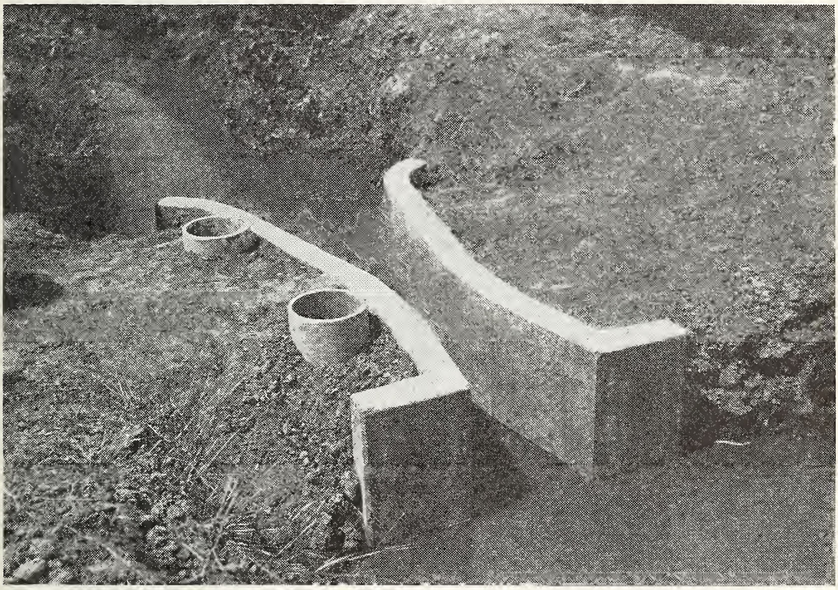

FIGURE 23.—The 9-inch flume under submerged flow conditions. The H_a and H_b stilling wells are 10-inch transite pipe cut to the proper length, with concrete plugs at bottom which support centrally the ⅜-inch guide rods for the measuring stick. The degree of submergence here is about 90 percent and the discharge 1½-second feet.

STILLING WELLS AND RECORDING INSTRUMENTS

Where conditions permit continuous free flow through the Parshall measuring flume, a simple staff gage fixed to the inner face of the wall of the converging section of the flume, at the H_a gage point, will permit reading the head within the limits of accuracy acceptable in irrigation practice. The best type for this purpose is the enameled gage graduated in feet, tenths, and hundredths. The gage is recessed in the face of the wall to a depth of $\frac{1}{16}$-inch, which permits the flowing water to pass across the gage smoothly and thus assures quite accurate readings of the H_a head (fig. 22).

To provide such a suitable recess in the wall of the flume and at the same time an anchorage for mounting the gage, the following method has been found practical: A strip of 16-gage galvanized iron having a width about $\frac{1}{16}$ inch greater than the enamel gage and of equal length, is mounted vertically on the casting face of the inside form at the exact distance back from the crest. Three screws through the form, top, center, and bottom, passed through holes equally spaced in the metal strip, are bedded in a 1- by 2-inch wooden piece. This simple arrangement makes up the assembly. As shown in figure 24, the wooden piece is cut about ½ inch short. The edges are beveled to secure the strip when cast in the concrete. In dismantling the form, the three screws are removed, freeing the form but leaving the wooden piece cast in the wall at the exact position for the staff gage.

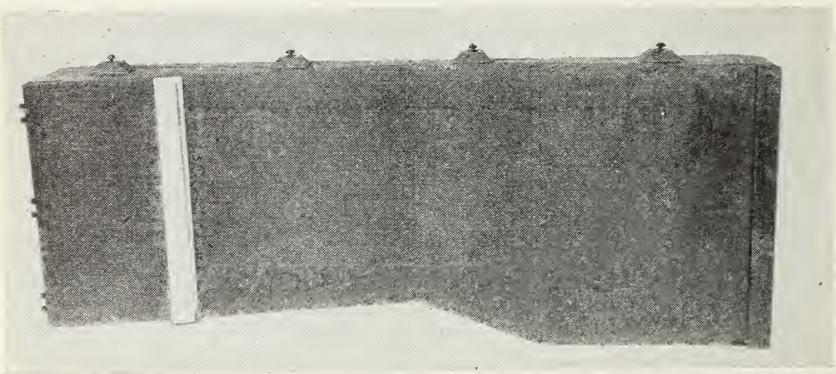

FIGURE 24.—Side view of inner form showing metal strip and beveled wood strip to be cast in the inside face of the wall of the converging section of flume for the purpose of mounting a vertical H_a staff gage, as shown in figure 22.

Because of the fluctuation of the water surface in the throat, at the H_b gage point, it is not possible to observe this head accurately enough by means of a staff gage. This head must be known when the flow becomes submerged, and to determine the effective degree of submergence the values of both heads must be ascertained within close limits. For such a condition of flow the measuring flume must be equipped with both H_a and H_b stilling wells (fig. 23).

Common 6-inch vitrified sewer tiles serve very satisfactorily as stilling wells for the 3-, 6-, and 9-inch flumes where the height of the wall of the converging section is 18 inches. For wall heights of 24 inches, it is recommended that 6-inch fiber pipe be cut into suitable lengths with a common coarse-toothed hand saw. As shown in figure 2, the stilling wells are provided with short inlet tubes, and each well must therefore be provided with a hole through the tile or pipe of the proper diameter and at a definite point from the bottom.

A quick way of making the hole in the tile is by shooting with a .45-caliber pistol or a .22-caliber with extra long cartridge. The gun should be securely mounted in a frame or held in a vise and the tile set up at close range, a foot or so from the muzzle of the gun, at the correct elevation for the bullet to pierce the wall at the desired point. To prevent the bullet from passing through both walls of the tile, a flat piece of steel plate should be placed inside the tile and a shield should be provided to prevent personal injury from spraying lead particles.

The holes in a fiber pipe may be put through with a common wood auger.

After the holes in the tile or pipe have been made at the proper height, the well is set upright on a common 1- by 8-inch board to receive the concrete plug at the bottom. Where several wells are to be prepared, this baseboard, about 16 feet long, is provided with

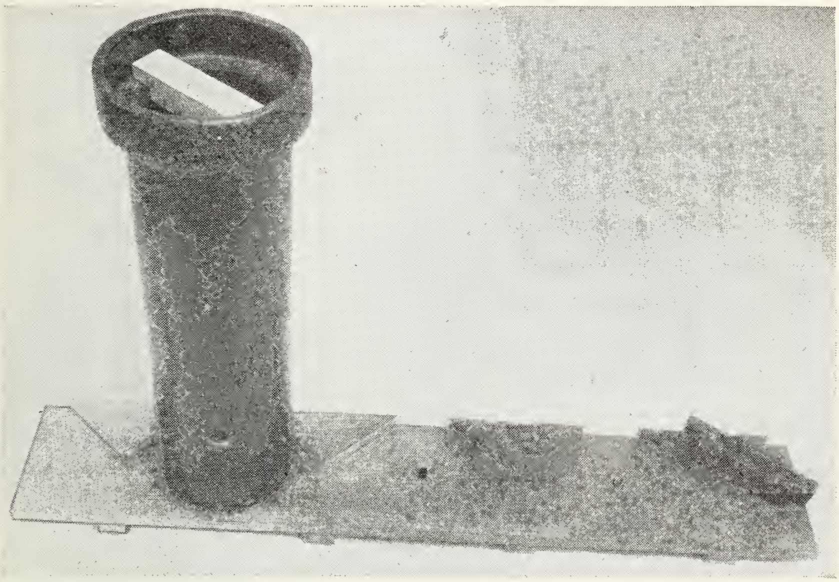

FIGURE 25.—Six-inch common sewer tile for H_a stilling well showing tube hole made by .45-caliber bullet. The triangular blocks permit the placing of the tile in exact position for centering the ⅜-inch guide rod. The block at right is the support for the top end of rod and the cartridge case through the baseboard holds the bottom end. Depth of concrete plug, 3¼ inches.

$\frac{7}{16}$-inch holes, along the center line, spaced at 11-inch intervals with guide blocks as shown in figure 25. From the back side of this board a used .45-caliber cartridge case is driven through each hole. When driven to their full length the cases will extend about ½ inch above the surface of the board. The purpose of the cartridge cases is to hold in position the bottom end of the ⅜-inch iron rod at the center of the well. The cases should be filled by a wooden plug or cement mortar to the elevation of the top side of the board. This permits the end of the rod to be cast flush with the bottom of the plug. The top end of the rod is held in the center of the well by means of a narrow block spanning the top. The rod should be about ¼ inch shorter than the tile or pipe, and to insure rigidity in the concrete plug, it should be scored or slightly bent at the lower end. If iron or steel rods are used it is recommended that they be given a double coat of red lead before being placed. If copper inlet tubes are used, galvanized rods will be unsuitable because of electrolytic action. Brass rods and tubes may be used where the condition of the water is suitable, but are more expensive. Tubes of ¾-inch wrought iron pipe are satisfactory.

After the form has been removed from the flume structure, the stilling well is set vertically on a firm foundation at an elevation such that the hole for tube agrees with the hole through the wall of the flume at the gage point. The tube is then inserted and grouted flush with the face of the wall, and a stiff mixture of mortar is placed around the tube on the outside of the well. This accomplished, the backfill is brought up to about 2 inches below top of flume wall. The top of the stilling well should be at or slightly above the top of the wall.

If the water supply passing through the flume carries considerable silt in suspension, deposit will occur in the wells. For this condition the wells should be flushed out occasionally by filling with water to full capacity and then stirring the bottom deposit vigorously with a stick. The agitated mud will be washed out through the inlet tube.

This type of stilling well is unsuited to use where a conventional float-recording instrument is to be operated in connection with the measuring flume. To meet such requirements it is necessary to construct, either of treated wood or concrete, a special compartment set alongside the flume. Such a box in plan would be about 2 feet square with the bottom 1 foot below the floor line of the converging section of the flume. A short ¾- or 1-inch tube, leading from the H_a gage point into the stilling well, must be provided, also a cover over the well and a suitable housing for the instrument. A part of the cover should be removable to permit cleaning operations. Since a staff gage in the well may be found impractical to read it is suggested that the measuring stick be used to determine the H_a head. In the event the flow will be submerged and an instrument record is desired, a well for the H_b head must also be provided.

The double-head recorder, equipped with two floats, usually operates with limited clearance between the floats. The H_a and H_b wells can be most conveniently made by constructing the box, about 2 by 4 feet in plan, with a thin partition or diaphragm to separate it into two watertight compartments. If a considerable amount of suspended load of silt or fine sand is carried in the water the wells will ultimately fill with deposit. It is practical to provide a flushing system for cleaning the wells. A 3-inch pipe, with valve, leads from the front end of the flume into the H_a well. An opening with 3-inch valve, at low elevation, in the partition provides for the scouring effect into the H_b well; thence, through a 3-inch pipe, which serves as the inlet to the H_b well, the course of the flushing stream is completed. After the cleaning has been accomplished the two valves are closed and the water surfaces in the two wells assume their normal levels.

Datum Point in Stilling Well and Measuring Stick

Because of the relatively small diameter of the stilling well it would be impossible to read accurately a staff gage set vertically in the well, but heads may be observed quickly and with reasonable accuracy by the use of the specially designed measuring stick described on page 60.

The base elevation, or datum, in each well must be referenced to the mean elevation of the crest of the flume. When the concrete plug is cast in the bottom of the well to support the vertical iron rod at its center, the top of the plug should be ½ to 1 inch lower in elevation than the crest when the well is set in permanent position beside the flume. After the wells have been backfilled the datum points are established in the following manner: An L-shaped frame is used, the short leg being exactly 24 inches long and the other long enough to reach beyond the rod in either well when the short leg is vertical at the midpoint of the crest. A piece of ½-inch square tubing, cut to the exact length of 24 inches, is dropped into the well over the ⅜-inch vertical rod. With the L-frame in position and the longer leg leveled carefully by means of a sensitive bubble tube, the distance that the top of ½-inch tube is below the top edge of the frame is the distance the bottom end of the tube is below the crest. This distance is estimated and the tube is withdrawn. Common ½-inch iron, or preferably, brass washers averaging about 1⁄16 inch in thickness, are dropped over the iron rod in numbers sufficient to approximate the distance from the top of the plug to the crest elevation. A check observation should now be made which will indicate whether additional washers

FIGURE 26.—The L-frame being used to check the datum point in stilling well. The rod at the left is resting on the midpoint of the crest; the ½-inch square tube is resting on the washer datum point in the well. The level bubble at the center point of the horizontal leg of the frame is in exact adjustment. This datum point was originally set in May 1941. By loosening the wing nut at the left, the rod may be withdrawn and then inserted inside the ½-inch square tube. These assembled parts are thereupon slipped into a deep groove on the underside of the horizontal leg of the frame and fastened in place by a slide-clip. This arrangement provides a convenient assembly for field use.

or thinner pieces are to be added or removed to produce exact agreement, as shown in figure 26.

This scheme of stilling wells and method of observing the heads was first tried out in the installation of about 125 measuring flumes of 6-, 9-, and 12-inch sizes built along the Pleasant Valley and Lake Canal, near Fort Collins, Colo., in 1941, in solving the problem of equitable service to the farmers who draw their irrigation supply from this source. The datum points in the wells of several of these flumes were checked with the L-frame in 1946, and many were found to be in exact agreement; others indicated that washers had been taken out or added, possibly with the intent of unfair measurement. The ditch rider, or superintendent, has knowledge of secret markings or headgate openings, which immediately show whether conditions of measurement are irregular.

It is suggested that the datum points in the wells for all measuring flumes be checked at the beginning of each irrigation season.

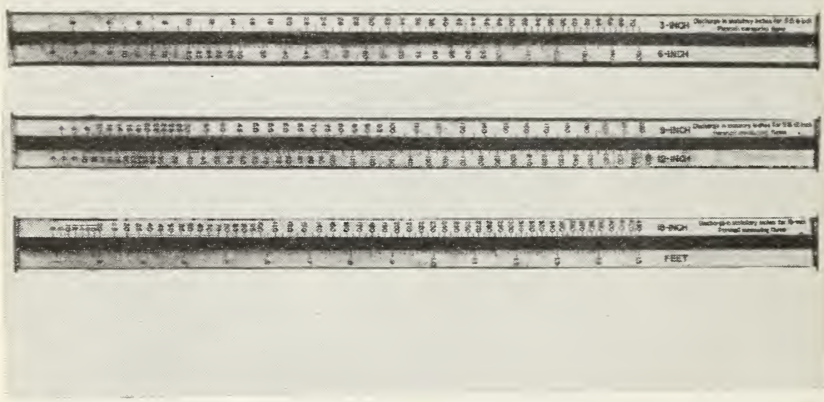

FIGURE 27.—The measuring stick of triangular cross section, showing the discharge scales in Colorado statutory inches for the 3-, 6-, 9-, 12-, and 18-inch Parshall measuring flume. The scale in feet permits observing the H_a and H_b heads to determine degree of submergence.

The specially designed measuring stick provides the means of reading accurately the H_a and H_b heads in the stilling wells. Two wooden sticks have been developed. The first (fig. 27) is triangular in cross section with 1½-inch faces and a length of about 23¼ inches, has a ½-inch hole throughout the entire axial length, and is shod with brass plates at each end. A piece of black rubber, three-eighths inch wide, is inlaid in the center of each of the three sides of the stick, extending the full length. This rubber strip has adjacent along each side a scale graduated in units of the Colorado statute inch (1 inch is equivalent to $\frac{1}{38.4}$ second-feet). One face carries the scales for the 3- and 6-inch measuring flumes; the second for the 9- and 12-inch flumes; and the third, for an 18-inch flume and a scale graduated in feet, tenths and hundredths. This latter scale permits observing the heads in feet, for the purpose of computing the percentage of submergence.

The black rubber strip is to show in marked contrast the wetted limit of the water surface in the well. Since this marking is directly adjacent to the graduated scales, the rate of discharge is read easily. This particular stick may be used directly with flumes ranging in size from 3 to 18 inches and having the H_a head limited to 1.5 feet. Longer sticks could be prepared to accommodate heads of 2.5 feet or more, with the scales graduated in second-feet.

The other design of measuring stick is more simple (fig. 28). It

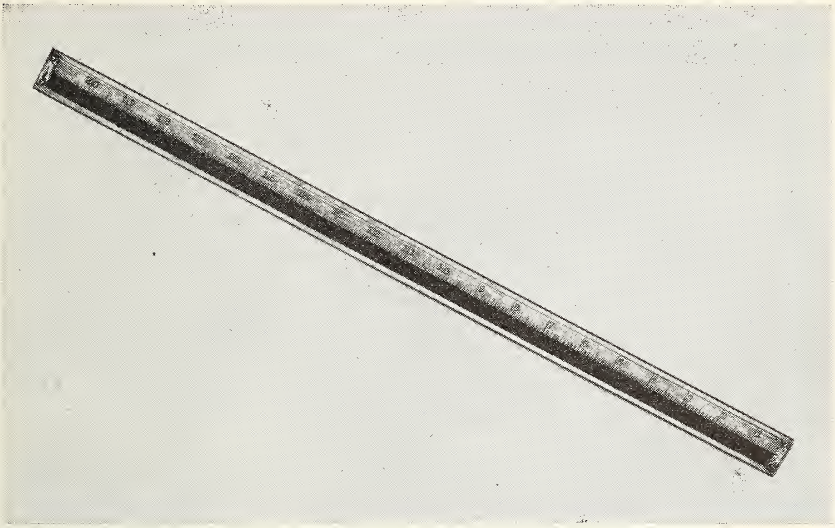

FIGURE 28.—Simplified pattern of measuring stick intended for observing the H_a and H_b heads in feet. The rate of discharge is obtained by reference to tables or diagrams.

is rectangular in cross section, ⅞ by 1⅜ inches, and 25½ inches long, with a ½-inch hole throughout its axial length and also with brass plates at each end. In one of the wider faces is inlaid a black rubber strip, ½ inch wide, with a simple scale in feet, tenths, and hundredths adjacent. This stick shows only the head H_a and H_b in feet. To determine the rate of flow it is necessary to refer to the discharge table for the particular size of flume in use.

To use the measuring stick, it is necessary merely to slip it over the ⅜-inch vertical rod in the well and then lower it until it comes to rest upon the datum or base established by the use of the L-frame. The stick should be lowered gently the last 2 or 3 inches in order to permit the water surfaces, in the well and flume, to equalize, owing to the displacement caused by the volume of the stick immersed in the water in the well. The water adheres instantly to the rubber surface. The stick is withdrawn and note is quickly made of the maximum water mark, which registers either the rate of flow direct or the head in feet. By estimation it is possible to determine the head accurately within about 0.002 foot. In hot weather the thin water film on the black rubber surface evaporates rapidly, and to obviate possible error it has been found that a slight oil film on the water surface in the well will make a more fixed marking on the rubber. Too much oil may render the stick useless.

When observing the heads to determine the degree of submergence it is suggested that the downstream, or H_b head be taken first, and then the upstream head, or H_a. Since the latter will be the greater in value, the last wetting of the rubber surface will exceed the former and reach into an unused area on the stick.

SUMMARY

Experience in the management and distribution of irrigation water indicates definitely the need of accurate and dependable measurements of flow: First, because equitable distribution of the common supplies is essential to harmony; second, because deliveries made in the proper and just amounts curtail waste, promote attentive practice, and generally bring about irrigation efficiency. Through systematic and careful measurements of delivery the greatest economy can be attained and increased acreages may be served adequately. It is contended that when farm deliveries are measured carefully, according to the rightful amounts of flow, the result will be a stretching of the supply for the benefit of farmers who otherwise would be denied water because of apparent shortage in the canal.

Weirs, when maintained under standard conditions, measure accurately, but field experience indicates that neglected maintenance and other limitations may make this type of device of questionable practicability. Weirs are unsuited to channels having slight grade. Free flow through a weir requires considerable loss of head or sacrifice of channel grade.

A widely adaptable means of measuring irrigation supplies at the source and in deliveries to farms. is the Parshall measuring flume.

This device has a number of advantages: It is accurate enough to meet practical needs; has the ability under almost all conditions of operation to clean itself of sand and silt which otherwise would cause doubtful measurements; will withstand a relatively high degree of submergence without affecting the indicated free-flow discharge shown by a single-head measurement; tolerates a high degree of submergence as a single-head measuring device, permitting operation with a relatively small loss of head; is operated readily to measure submerged flows by use of the two observed heads; has a discharge capacity ranging from less than 0.1 second-foot through a 3-inch flume to more than 2,000 second-feet through a 40-foot flume; cannot be easily altered in dimensions or influenced to produce unfair or erroneous measurement; is constant in its dimensions and setting and therefore dependable in accuracy; may be made of metal, wood, or concrete. The large flumes are usually reinforced-monolithic concrete, but for the small sizes (2 feet and under) metal is often used, as metal flumes are portable and easily adapted to any desired operation conditions.

The construction of small concrete measuring flumes has been greatly facilitated by the use of a knock-down portable form particularly adapted to the 3-, 6-, and 9-inch sizes.

Measuring sticks of special design have been found practical for observing the H_a and H_b heads in tile stilling wells of the measuring flume, or may be so graduated as to show the rate of flow over a weir or through the measuring flume direct.

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