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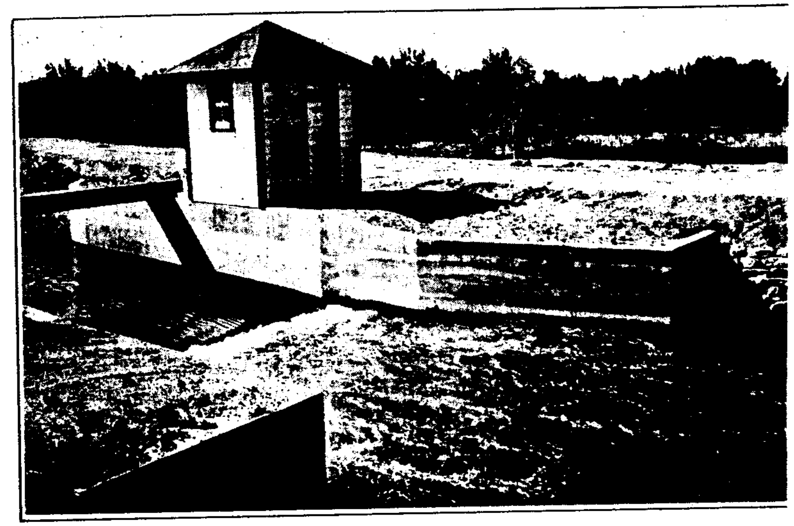
PARSHALL FLUMES OF LARGE SIZE



Twenty-foot Parshall Measuring Flume for Bijou Canal, South Pla
Valley, near Greeley, Colorado.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
DIVISION OF IRRIGATION ENGINEERING AND WATER CONSERVATIO
IN COOPERATION WITH
COLORADO AGRICULTURAL EXPERIMENT STATION

Agricultural Experiment Station—Agricultural Extension Se
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COLORADO
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PARSHALL FLUMES OF LARGE SIZE[1]

By RALPH L. PARSHALL
Senior Irrigation Engineer, Division of Irrigation
Bureau of Agricultural Engineering, United States
Department of Agriculture

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Experiments on a device called the Venturi flume were made in 1915 by V. M. Cone at the hydraulic laboratory of the Colorado Agricultural Experiment Station. Later experiments on the same device were made by Carl Rohwer and the writer in 1920 at both the hydraulic laboratory at Fort Collins and the Bellvue laboratory on the Cache la Poudre River, 8 miles west of Fort Collins. This device had converging entrance and diverging outlet sections, joined by an intermediate throat. The walls were either vertical or inclined outward, and the floor was level. In 1922 the writer proposed somewhat radical changes in the design of this device—the angles of convergence and divergence were changed, the lengths of these sections were altered, and the floor in the throat was sloped downward, forming a fixed crest and control at the junction of the converging section and the throat. The walls were made vertical and the floor of the converging section level, while the floor of the diverging section inclined upward to the lower end of the structure. It is this device that the Irrigation Committee of the American Society of Civil Engineers has named the Parshall Measuring Flume. The development of the larger flumes, however, has been largely through the design of structures for particular locations, especially in the Arkansas River valley.

[1] Prepared under the direction of W. W. McLaughlin, Chief, Division of Irrigation, Bureau of Agricultural Engineering, and in cooperation with the Colorado Agricultural Experiment Station. Revised edition prepared by Carl Rohwer under the direction of George D. Clyde, Chief, Division of Irrigation Engineering and Water Conservation, Soil Conservation Service.

The general ratio of dimensions that applies to the small-sized flumes has not been followed for the large flumes. In table 1 are given the main dimensions for sizes ranging from 10 to 50 feet in throat widths and having maximum capacities from 200 to 3,000 second-feet under conditions of free-flow discharge.[2] The flumes may successfully measure greater flows than those indicated as the maximum in table 1, but under ordinary channel-capacity conditions the size of flume and the related maximum flow are approximately as shown in the table. For example, in a channel having 600 second-feet capacity, it is probable that under average conditions the 15-foot flume would be suitable, provided a free-flow discharge could be secured.

In small flumes the length of the wall of the converging section is W/2+4 in feet, W being the length of crest or size of flume in feet, and the point of observing the upper head, H_A, is two-thirds of the length of the wall measured back from the flume crest. For the large flumes the length of the converging section generally has been made considerably longer than W/2+4 in order to obtain a smoother flow as the water passed through this part of the structure. The location of the gage point, H_A, however, is maintained at 2/3(W/2+4) back from the crest. The lower gage, H_B, is located near the downstream end of the throat section (see table 1 and figures 4 and 5), and the head there is communicated to the H_B stilling well through a pipe of ample size which is also a part of the flushing system. For both the H_A and H_B gages, the zero point is at the elevation of the crest. Thus, the depth or water pressure indicated by the H_B gage is depth above the crest, and not the full depth of water at the pressure orifice.

The Setting of Large Flumes

For the successful operation of the large flumes, it is important to have the crest set at the proper elevation with reference to the grade line of the channel. It will be found more convenient to set the flume so as to operate at less than the critical degree of submergence, which will eliminate the effect of back-water and thus have the rate of discharge a function of the size of flume and the upper head, H_A. Quite often, however, such a setting results in too much loss in head, and at the same time gives to large discharges high exit velocities which erode the downstream section of the channel. Often particular attention must be given to the increased depth of water upstream from the flume after it has been installed. The freeboard of canal banks must be considered, as well as the possibility of interfering with

[2] See pages 25 to 37 for discussion of free flow and submerged flow.

Table 1.—Relative dimensions for Parshall Measuring Flumes of large size.

Size (throat width)	Free-flow capacity		Axial length			Width		Wall depth converging section	Vertical distance below crest		H_A gage distance (not axial)**
	Max.*	Min.	Converging	Throat	Diverging	Upstream end	Downstream end		Dip at throat	Lower end of flume	
feet	sec. ft.	sec. ft.	feet	feet	feet	feet	feet	feet	feet	inches	feet
10	200	6	14	3	6	15'7.25"	12'0"	4	1'1.5"	6	6'0"
12	350	8	16	3	8	18'4.75"	14'8"	5	1'1.5"	6	6'8"
15	600	8	25	4	10	25'0"	18'4"	6	1'6"	9	7'8"
20	1000	10	25	6	12	30'0"	24'0"	7	2'3"	12	9'4"
25	1200	15	25	6	13	35'0"	29'4"	7	2'3"	12	11'0"
30	1500	15	26	6	14	40'4.75"	34'8"	7	2'3"	12	12'8"
40	2000	20	27	6	16	50'9.5"	45'4"	7	2'3"	12	16'0"
50	3000	25	27	6	20	60'9.5"	56'8"	7	2'3"	12	19'4"

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

* For special conditions these maximums may be exceeded if the depth of the flume is increased, without impairing the accuracy of the device. However, if large increases in capacity are necessary, the axial dimensions should also be modified. Information regarding these changes may be obtained by writing to the Division of Irrigation, Soil Conservation Service, Colorado A and M College, Fort Collins, Colorado.

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

the diversion through the headgates of the full capacity of the canal. In irrigation practice, it is sometimes found necessary to determine the flow accurately for the smaller discharges, while when the supply in the river is ample to provide a full head in the canal, accuracy of measurement is not so important. To meet such conditions, the practice in establishing the proper elevation of the crest has been to provide a free-flow condition for the lower flows and allow a submerged flow condition for the greater discharges. This setting is desirable because of the lessened exit velocities for the larger flows and minimum loss of head through the structure.

To illustrate the method used in determining the proper elevation of crest, an example applicable to a reasonably large canal is given. The Holbrook Canal, shown in figure 1, is used as the example. The discharge curve for the old rating flume on this canal was based on a few current-meter gagings that established a rating curve that was approximate only, because of the changing conditions of the channel, but was accurate enough for use in determining the crest elevation of the new flume. Previous attempts to establish a dependable rating curve based on current-meter gagings had been entirely unsatisfactory. At times more than 2 feet of sand had been observed on the floor of this flume, while later this deposit had been scoured out and moved downstream. In one observed instance, a depth of more than 1 foot of sand was deposited upon the floor in less than 2 hours. Because of this constantly shifting condition, the uncertainty of

Figure 1.—Old concrete rating flume and gage house on Holbrook Canal, typical of many old structures replaced by Parshall Measuring Flumes.

determining the flow by use of the rating curve was apparent, and the setting of the crest elevation of the new flume to meet such conditions, likewise, could not be accurately determined.

The first appropriation right of the Holbrook canal to the use of water from the Arkansas River is for 155 second-feet. In this case it was required to set the crest so that this discharge would be free flow and maximum discharge would be delivered under submerged-flow conditions. A width of 20 feet was chosen as the best size of structure and it was decided to place the new flume just upstream from the old concrete rating flume, so that the old structure would serve as a protection against erosion. From current-meter gagings made previous to the installation of the new flume, it was found that for a discharge of 155 second-feet through the rating flume the depth of water on the staff gage was, on the average, about 2.25 feet. Had this been approximately a fixed stage, the crest elevation for the 20-foot flume with respect to the staff gage, computed from the free-flow discharge formula $Q=76.25H_A^{1.6}$ (table V, page 30), should have been about 1 foot for the limiting submerged flow of about 80 percent.

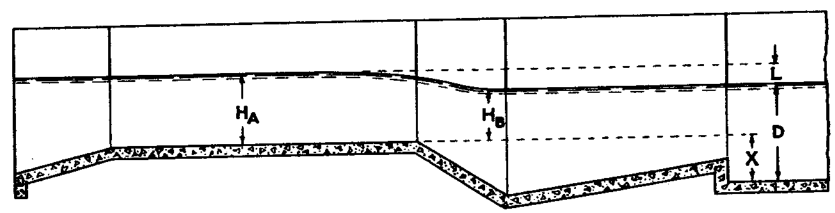

Figure 2.—Section of flume as an aid in the determination of the proper crest elevation.

To arrive at the elevation of 1 foot, refer to figure 2. It will be observed from the discharge given in table V for a 20-foot flume, that the H_A head for a discharge of 155 second-feet is about 1.56 feet. For a setting of limiting submergence at 80 percent, the H_B gage would be about 80 percent of 1.56 feet, or 1.25 feet. At this degree of submergence, the water surface downstream from the H_B gage is essentially level, and the loss of head or grade to the staff gage in the rating flume may be neglected. Since the average staff-gage reading is taken as 2.25 feet with the H_B gage estimated to be 1.25 feet, the difference (X in figure 2) of 1 foot will be the elevation of the crest above the zero point of the rating-flume gage.

Because of the wide range of gage heights in the rating flume, with the discharge remaining approximately constant, it is better to base the elevation of crest on the condition of maximum rating-flume gage. For this condition, the depth or staff-gage reading in the rating flume may reach 3.25 feet, and for such a limiting stage the crest of the new structure should be 2 feet (3.25 - 1.25) above the floor of the old rating flume to measure 155 second-feet under free flow—that is, with the degree of submergence not exceeding 80 percent.

After approximating the elevation of the crest of the flume at 2 feet, for a discharge of 155 second-feet at about 80 percent submergence, it is necessary to determine the condition of flow for large discharges. About 3 years before this 20-foot Parshall flume was built, there was a period when there was a discharge of 558 second-feet, as determined by a current-meter gaging with a staff-gage reading of 6.04 feet in the rating flume. With the crest set at 2 feet, the H_B gage would be approximately 4.04 feet, and by use of the submergence correction diagram (figure 13, page 36) it is found that for this discharge the degree of submergence will be about 95 percent, and the H_A gage will read 4.25 feet. (See pages 9 and 10 for details of method.) Therefore, the crest of the new Holbrook flume was set 2 feet higher in elevation than the zero of the staff gage in the old rating flume.

In planning such large flumes it is necessary to know, within reasonable limits, the depth of water in the channel for any particular discharge. As previously mentioned, it is not unusual to find that one or more limitations in measurement are imposed—that is, if conditions warrant, the lower rates of discharge should not be submerged or, if submergence is necessary, it should be in the least possible amount and for maximum discharge the degree of submergence should not exceed from 95 to 98 percent with the lower percentage preferred. To meet these requirements, it is necessary to investigate the problem by considering various sizes of flumes, as well as the cost of the proposed new structure.

Let it be assumed that it is required to provide a flume of the proper size and setting in a channel 50 feet wide, the capacity of which is 950 second-feet, with submergence not exceeding 80 percent for a discharge of 500 second-feet, and with depth and discharge relationships at the site of the installation as follows:

Gage height feet	Discharge sec.-ft.	Gage height feet	Discharge sec.-ft.
0.5	18	3.5	398
1.0	45	4.0	500
1.5	86	4.5	607
2.0	145	5.0	718
2.5	218	5.5	892
3.0	303	6.0	949

First, consider a 20-foot flume. For a free-flow discharge of 500 second-feet the H_A gage will be 3.24 feet (see table V) and the H_B gage 2.59 feet at 80 percent submergence. This percentage of submergence is illustrated in figure 3. In the foregoing tabulation a depth of 4.0 feet downstream from the proposed flume is required for this discharge. Since for this submergence the water surface at the H_B gage point is practically at the same elevation as it is downstream, X, the elevation of crest above bottom of channel (figure 2) is 4.00—2.59=1.41 feet. For the maximum discharge of 950 second-feet with this setting and size of flume, it is necessary to determine the degree of submerged flow. For a discharge of 950 second-feet the flow will be submerged. To determine the actual condition, first assume the submergence to be 90 percent. Since the canal gage is 6.0 for 949 c.f.s., the H_B gage reading will be approximately 6.0—1.4, or 4.6 feet. For 90 percent submergence, H_A will be 4.6/0.90 or 5.11 feet, and the corresponding free-flow discharge, 1,037 second-feet. (See discussion of submerged flow, pages 35 to 37). From the correction diagram (figure 13) it is found that the correction for submergence is about 145 second-feet, giving computed discharge of 1,037—145, or 892 second-feet. Since this discharge is too small the submergence must be less. For 88 percent submergence, the H_A gage

Figure 3.—A discharge of 550 second-feet passing through the throat section of 20-foot flume in the Holbrook Canal with 80 percent submergence.

is 5.23 feet and the computed discharge is 972 second-feet. At 89 percent submergence, the computed submerged flow is 934 second-feet. The actual submergence is therefore between 88 and 89 percent. For a 20-foot flume set 1.4 feet above the bottom of the channel and discharging 950 second-feet, with a submergence of 89 percent, the loss of head (figure 14, page 37), is about 1 foot. In this case, therefore, the increase in depth upstream from the proposed structure would be 1 foot more than the amount the flume was set above the rating flume grade, which might seriously reduce the freeboard of the canal banks and also interfere with the diversion or entrance conditions at the headworks of the canal.

For a 25-foot flume to measure 500 second-feet at 80 percent submergence, it is found that the height of crest above the bottom of the canal should be about 1.7 feet. At this elevation of crest it is also found that the maximum discharge of 950 second-feet will occur when submergence is 91 percent. From the diagram shown in figure 14, the loss of head for this maximum condition of discharge and submergence is about 0.7 foot. The decision as to which size of flume to select depends largely upon whether or not the loss of head of 1 foot for the 20-foot flume is too great for economical operation, or whether, on the other hand, the cost of a 25-foot flume of similar construction would be excessive. It will be noted that the larger flume must be set higher, but the loss of head would be less. Either size of flume would satisfactorily measure the flow.

As in the case of the Holbrook flume, there naturally arises the problem of increased depth of water upstream from the new structure, due to raising the crest and decreasing the width of the channel. After the Holbrook flume was built, 550 second-feet was measured through it with submergences of 81 percent and the upper gage (H_A) at about 3.5 feet. For the condition of 81 percent submergence, the loss of head from the H_A gage point to the upper end of the converging section of the flume is about 0.33 feet. For this condition the depth upstream from the Parshall flume is 5.83 feet (2.00+3.50+.33). Prior to the construction of this flume a gage height of 6.0 feet was noted in the old rating flume for approximately the same discharge when sand was filling the channel. This comparison shows that the filling in of sand in the channel caused the gage height to increase more than reducing the channel to a 20-foot throat and raising the flume floor 2 feet above the grade of the old rating flume. This condition is cited merely to indicate that under normal shifting conditions on this particular canal, the change in depth was greater than that caused by the installation of the 20-foot flume.

Construction of Large Flumes

Reinforced concrete has been used very largely in the construction of the large flumes, but concrete blocks may be used instead of reinforced concrete. Large flumes may also be constructed of wood. Figure 4 gives a design showing the principal dimensions for a concrete 30-foot flume, and figure 5 gives a design for a frame structure having a throat width of 20 feet.

The reinforced concrete structures are of monolithic construction, with steel reinforcing bars cast into the walls and floor (figure 6). Because of the wide span, it is not feasible to provide cross bracing or struts between the tops of walls, and counterforts have proved to be satisfactory for supporting 7-foot walls in 20-, 30- and 40-foot flumes, at the same time providing ample strength to sustain the backfill pressure (figure 7). It will be noted in figure 4 that substantial footings are shown. The bases for such footings should be firm and well prepared, and with the entire floor of the structure acting as a base, little or no settlement has been observed in the large concrete structures. The longitudinal and transverse beams under the floor should have U-shaped pieces of reinforcing bars inserted in the top surface of these beams at suitable intervals so that the bars in the floor may be threaded through them to secure rigid contact between the beam and floor. These beams provide strength against heaving or bulging of the floor. High-grade concrete should be used in the construction of the flumes. Clean sand and gravel are essential and a minimum of water should be used in mixing the concrete.

The essential feature in the building of the flumes is to have the finished dimensions and alignment correct. The floor of the converging section should be level. The downward-sloping floor in the throat should be a plane surface, pitched to the proper dimensions as shown. The floor of the diverging section slopes upward, the line of intersection of these two surfaces being level transversely. The most important feature of these flumes is the uniformly level floor of the converging section, and especially the uniformly level, straight crest at the junction of this floor and the floor of the throat. To provide a sharp and definite edge to serve as the crest, it is recommended that a straight, substantial angle iron be leveled and securely fixed in the proper position. For concrete structures this may be cast in the floor with the ends of the angle iron extending 2 or 3 inches back into the side walls of the structure. Holes provided through the vertical leg of the angle iron at about 2-foot intervals, through which short pieces of reinforcing steel or bolts may be inserted and cast into the floor, will

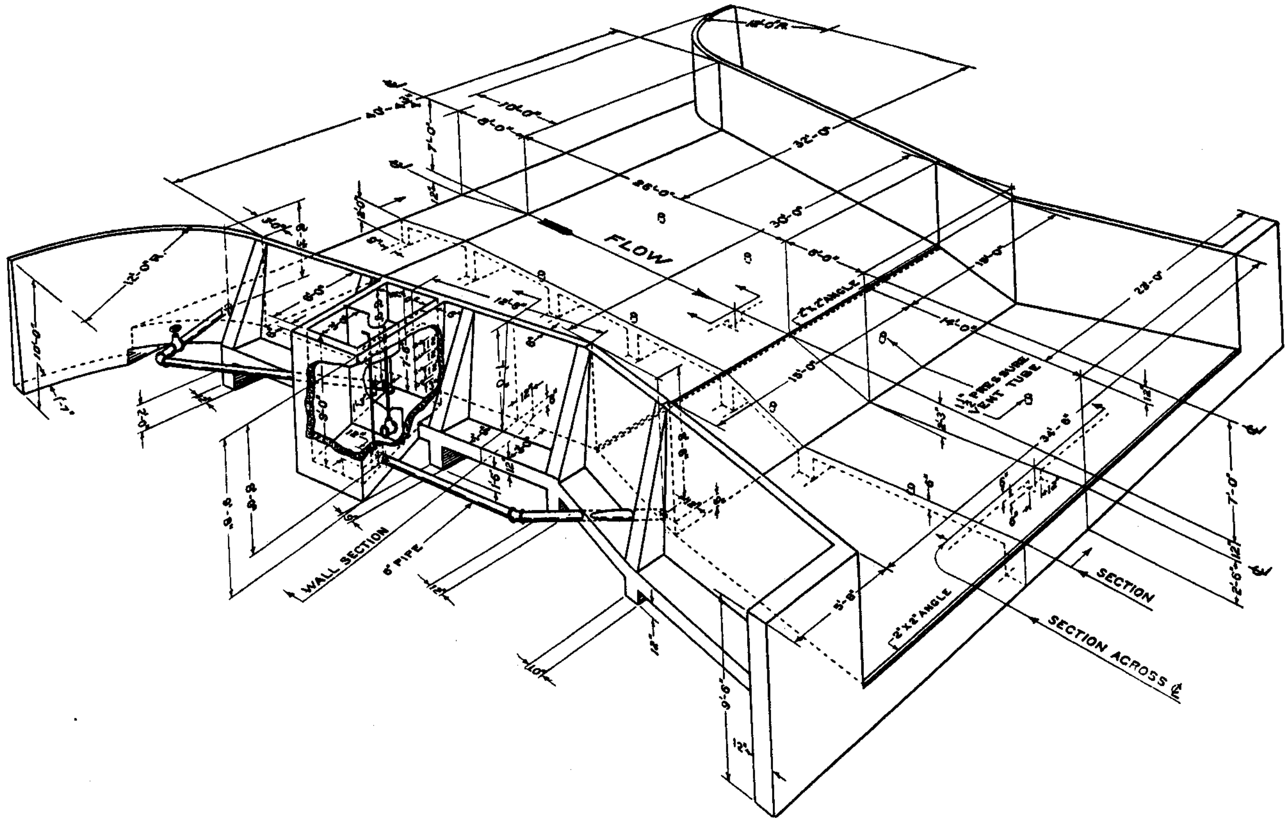

Figure 4.—Large Parshall Measuring Flume of reinforced concrete, with 30-foot throat.

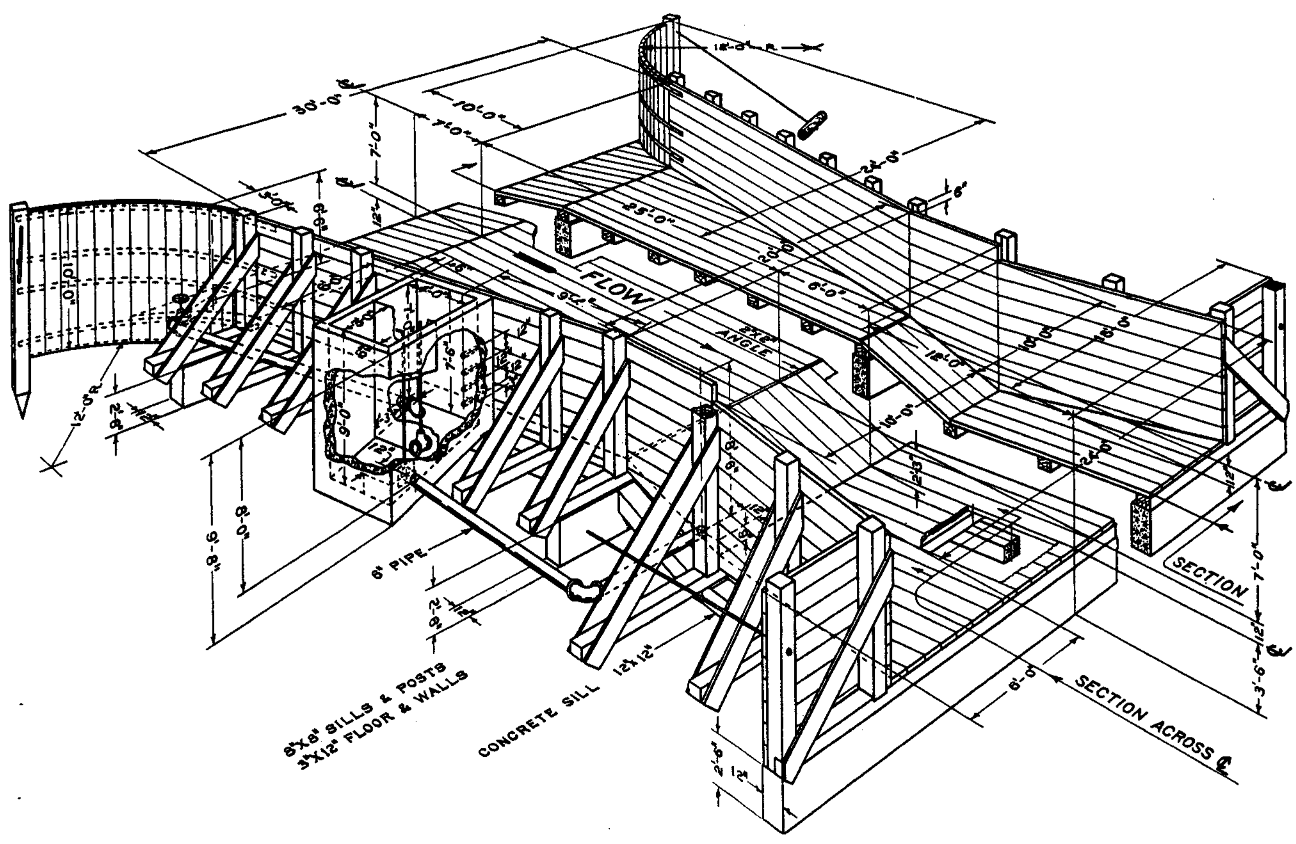

Figure 5.—Large Parshall Measuring Flume of timber construction, with 20-foot throat.

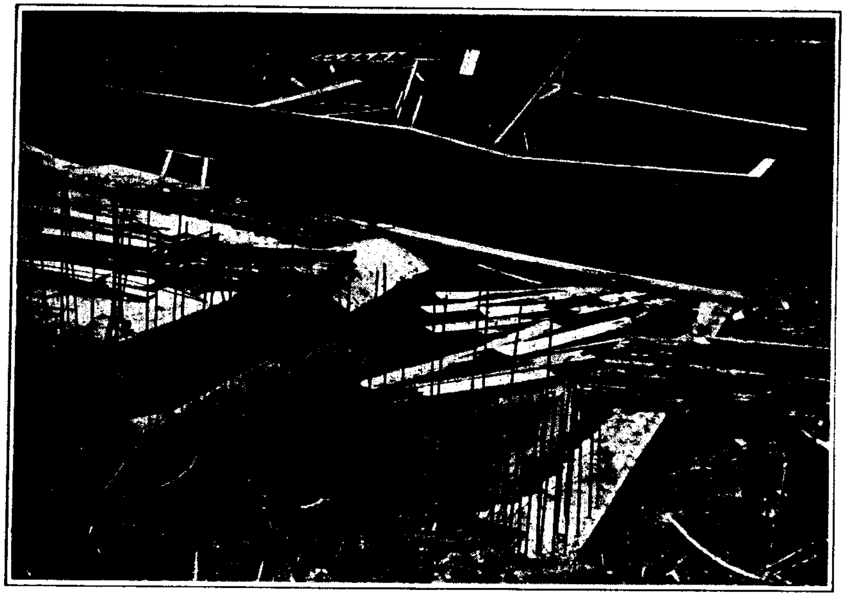

Figure 6.—Partly completed 20-foot Parshall Measuring Flume in Bijou Canal near Greeley, Colo., showing vertical reinforcing bars in place.

securely anchor the crest in place. It is recommended that an angle iron be placed at the downstream end of the diverging section also, if the structure is built of concrete, as a protection to the exposed edge. The inside faces of the walls should be smooth, straight and vertical, and the outside faces should have the required batter. The floors of concrete structures should also be provided with pressure vent tubes, as indicated in figure 4. The inclined apron at the upstream end of the flume, as well as the curved walls reaching back to the banks of the channel which serve to lead the stream of water into the entrance of the flume with slight loss of head, should all be smooth and regular to insure good flow conditions.

The utility of the structure lies in the accurate measurement of the discharge. As the rate of flow is a function of the relationship of the depths of water at the upper and lower gage points in the flume, it is important that the distances to these points be carefully determined. Table 1 gives the distances to the upper gage, H_A, in feet, measuring back from the end of the crest along the wall of the converging section. This point may be located on either side of the structure. Figures 4 and 5 show inlet tubes leading from the inside face of the wall into the H_A gage well, which is cast as an integral part of the structure. These inlet

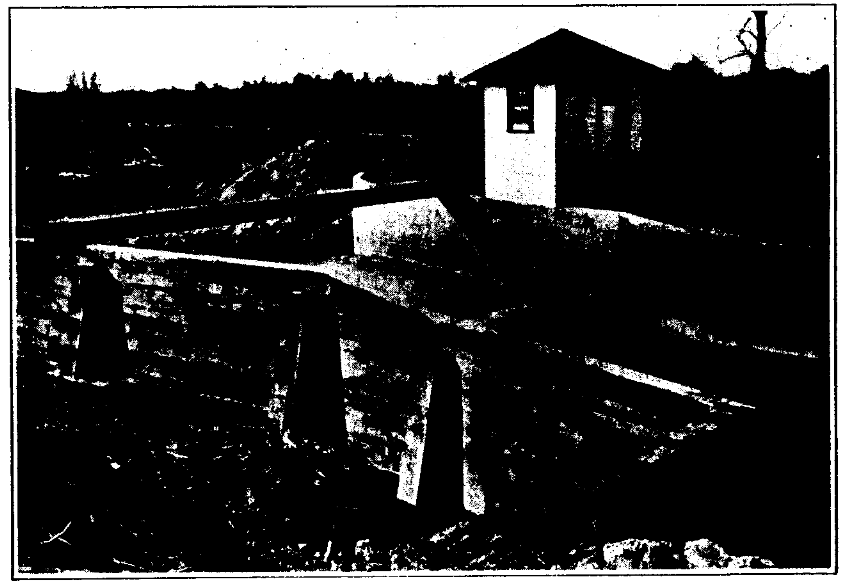

Figure 7.—Flume wall with counterforts, 20-foot Parshall Measuring Flume in Bijou Canal.

points are located in a vertical line, 12 inches apart, with the bottom one about 3 inches above the floor line. The lower or throat gage, H_B, is at a point near the downstream edge of the throat. (See note, table 1). The inlet openings into the flume for both H_A and H_B gages must be set flush with the inside face of the wall, and must be permanently fixed in position and neatly finished.

Concrete blocks may be used in the construction of large Parshall flumes. When this type of construction is used the floor of the flume is made of monolithic concrete and only the walls are made of blocks. This eliminates the expensive form work for the walls and has proved to be an economical method of construction. The design of a Parshall flume with a 10-foot throat, and side walls of concrete blocks is shown in figure 8.

Careful planning is required when building a flume by this method. The walls must be reinforced by horizontal steel rods laid in the mortar between the courses of blocks and by vertical rods set in the floor and extending up through the holes in the blocks. These vertical rods should be set by means of a template so that the spacing of the rods will coincide with the holes in the blocks. The template should be made to fit the particular type of

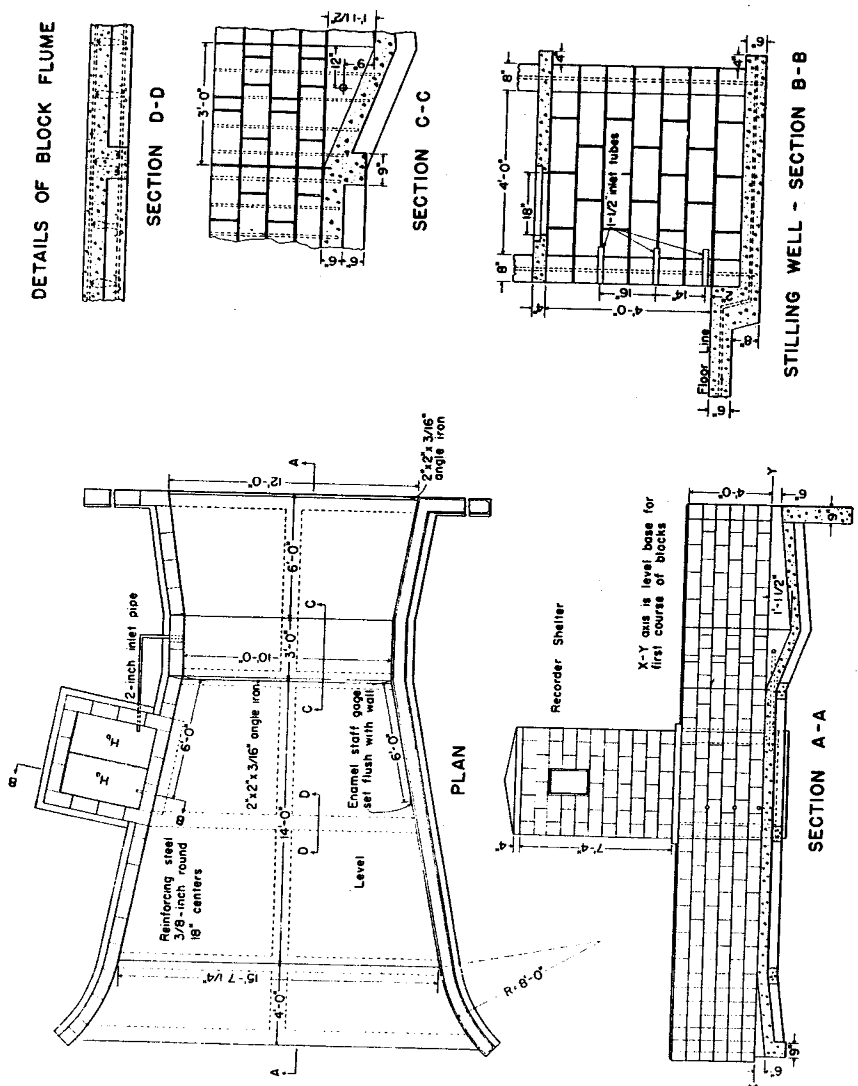

Figure 8.—Parshall Measuring Flume of concrete block construction, with 10-foot throat.

block being used. After the walls are completed the holes in the blocks are carefully filled with concrete to bond the walls with the floor.

Since the floor of the flume slopes downward in the throat and upward in the diverging section, the walls in this part of the flume up to the floor line of the converging section should be made of concrete as shown in the figure. When this plan is followed all the courses can be laid without cutting the blocks to fit the sloping floor.

The large concrete blocks can not be used to build the curving walls at the upper end of the flume. Half blocks should be used for this purpose. A smooth wall can be obtained if the blocks are laid without breaking joints as shown in the figure. If the walls of the flume are not more than 3 feet high they are strong enough to support the backfill of earth. Higher walls should be strengthened by tie-rods anchored to deadmen buried in the ground. The tie-rods should be attached to the vertical reinforcing rods in the walls to distribute the load.

The best grade of concrete blocks should be used for the walls. Cinder or pumice blocks are not suitable for this type of construction. A dense concrete is important. This reduces the absorption of water by the walls and consequent deterioration due to frost action. After the walls are laid they should be given a wash coat of white portland cement or other suitable sealing compound.

Flumes built by this method have been in successful operation for several years. They have shown no signs of cracking or disintegration. Because of the low cost of these flumes this method of construction should always be investigated when planning to build a Parshall flume.

Large Parshall flumes may also be successfully constructed of wood where the cost of concrete is excessive or the soil is unsuitable for concrete. The design of a wooden flume with a 20-foot throat is shown in figure 5.

To insure better alignment for the frame structure along the floor line, it is recommended that the first courses of wall planks be set and the floor planks then be carefully fitted into place. This arrangement insures against the bulging or crowding inward of the bottom wall planks, due to the hydrostatic and earth pressure against the outside face of the flume wall. Also, experience teaches that the planks should not be matched too closely, as the swelling of the wood may cause the floors to warp or heave, thus making an irregular surface. A crack one-eighth- to one-fourth-inch wide should be left between adjacent planks. Parting stops between the planks to prevent leakage are thought to be unnecessary.

As for the concrete flume, an angle-iron crest is highly desirable. After setting the floor of the converging section with the ends of the planks at the crest line smooth and even, the angle-iron crest should be set flush with the floor surface and held firmly in place with substantial lag screws. The heads of these lag screws, set at about 2-foot intervals, may project above the surface without material interference with the proper working of the flume. If properly set, this angle-iron crest will be straight, at right angles to the axis of the flume, with its surface level throughout.

For the frame structure (figure 9) the curved transition at the entrance is formed of 3- by 6-inch pieces set on end and held in place by 1/4x3-inch steel bands, properly spaced with one end securely bolted to the upstream end of the wall of the converging section and the other to a post firmly set in the bank of the channel. These bands, when in place, form a smooth curve to support the vertical pieces which are held in place by the backfill. The framing of the large structures can be accomplished by

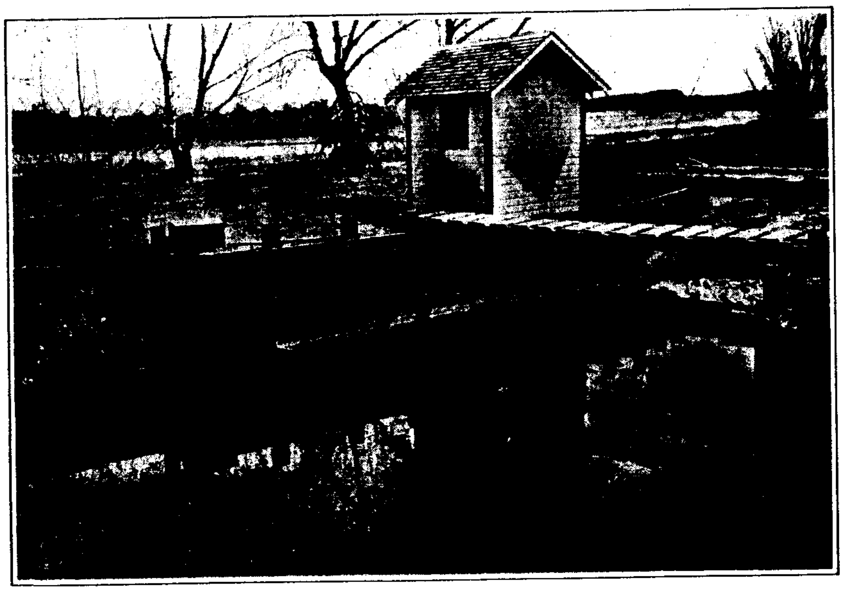

Figure 9.—Large Parshall Measuring Flume of timber construction in Rocky Ford Highline Canal, with 15-foot throat, discharge 101 second-feet, submergence 19 percent.

any experienced carpenter. After the work has been completed, it is desirable to trim the tops of the posts to a uniform height as a matter of general appearance. As a measure of economy the use of lumber pressure-treated with creosote or other preservative is fully warranted.

Wooden Parshall flumes in ditches carrying water during the winter season have been subject to scoring due to angular pieces of ice striking against the side walls of the lower end of the converging section. For this reason it is thought advisable to protect the angle at the junction of the walls of the throat and converging section by means of a vertical strip of heavyweight sheet steel, shaped to the proper angle, so that when in place it will fit snugly against the side walls. It has also been the practice to provide a substantial footbridge spanning the converging section at a point about three-quarters the length of this section, measured back from the crest. This bridge is to provide a means of crossing and may be used in making current-meter gagings.

It is not possible to state the cost of these structures, as many factors are involved which influence the final figure. From the designs submitted, it is possible to approximate the amount of material, either in lumber or concrete. The local market prices are then used to estimate the cost of materials. The excavation required, accessibility, transportation, and other features ultimately enter into the cost. Treated-lumber flumes should cost somewhat less than those made of concrete. In some instances, however, the difference in cost for the two types has been small.

Stilling Wells

For making accurate discharge measurements in large flumes, it has been found necessary to determine the effective heads carefully. A staff gage for the determination of the H_A reading, if attached to the inside face of the flume wall, can be read only approximately because of the fluctuations of the water surface, and the turbulent condition of the water within the throat of the structure makes it quite impossible to obtain accurate H_B readings by means of a staff gage located in that section of the flume. In order to obtain reliable and accurate gage readings, a double stilling well (figure 10) is provided at a point where the gage inlet tubes will pass directly into the H_A compartment, while the head for the H_B gage is brought back to the other compartment through a suitable pipe leading from the proper point in the throat section. A reinforced concrete stilling well with a quarter-inch steel plate diaphragm cast into the walls and bottom of the well to provide the water-tight H_A and H_B compartments, is rec-

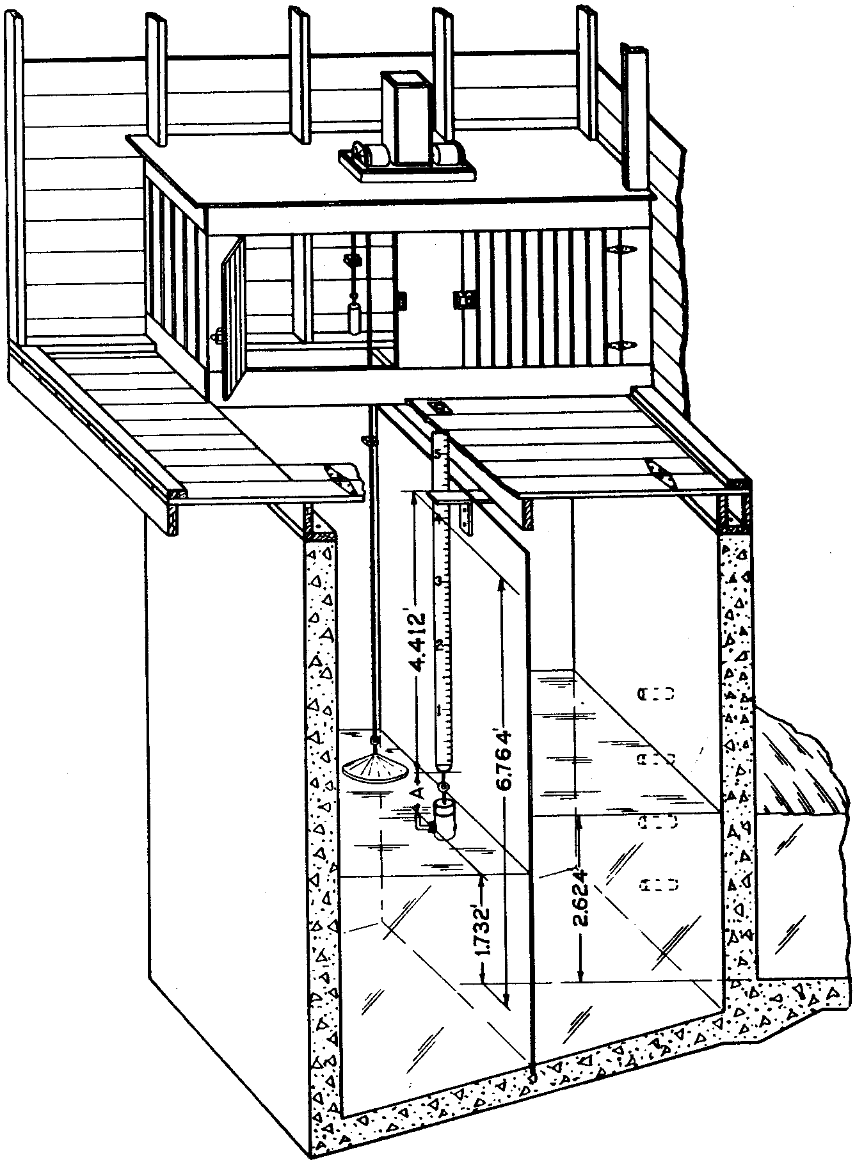

Figure 10.—Method of determining actual values of the H_A and H_B heads in feet, for comparison with indicated values on recorder chart.

ommended. A ladder way for each compartment, improvised by fixing U-shaped pieces of reinforcing steel in the walls of the wells at suitable places, is also suggested.

Because of the depth of the wells, it has been found difficult, if not impracticable, to clean out the deposit of mud and sand by means of bucket and rope. Under some conditions, where the water passing through the flume is heavily laden with silt, sand and suspended matter, the stilling wells soon become fouled. As a practical means of clearing the wells, a flushing system has been developed which has been found to be effective. Leading from the curved wing wall at the upstream end of the structure is a 6-inch metal pipe which discharges into the H_A stilling well. This pipe has a substantial gate valve, located as shown in figures 4 and 5. At the outlet end in the well is an elbow pointed downward. In the steel diaphragm is a 6-inch circular opening near the floor line, and attached is another similar gate valve. The 6-inch pipe leading from the H_B well to the throat of the flume completes the system. To flush the wells, open the valve on the inlet pipe and the valve on the steel diaphragm, and raise the slide gate in the H_B well. Unless the submergence through the flume is very high, the hydrostatic head between the inlet and outlet ends of this flushing system is sufficient to provide a good scouring velocity through the two wells. The elbow, pointed downward in the H_A well, will move the deposit on the inclined floor toward the opening through the diaphragm, and since the outlet from the H_B well is at a low elevation, the deposits will tend to move to this point and eventually be carried out and discharged back into the throat section of the flume. Under extreme silt or sand conditions, a 5- or 10-minute flushing every day should maintain the wells in good order. When all the valves are closed the water levels in the two wells will readily assume their normal elevations.

It will be noted that the valve in the pipeline leading to the H_A well is shown set back at some distance from the inlet end. For winter operations, the danger of damage to the valve by freezing is lessened by having this valve well back from the exposed wall surface. For convenience in the operation of the valve, a pit may be provided with a trap door and lock, or a key stem may extend to the ground surface.

The slide gate at the upper end of the outlet pipe from the H_B well will not need to be a close-fitting valve. A simple gate may be constructed (figure 11) by using a standard 6-inch cast-iron flange screwed on the projecting end of the pipe. A lug and cover plate prepared as shown bolted on opposite sides of the flange, serve as guides for the slide valve. The latter may be

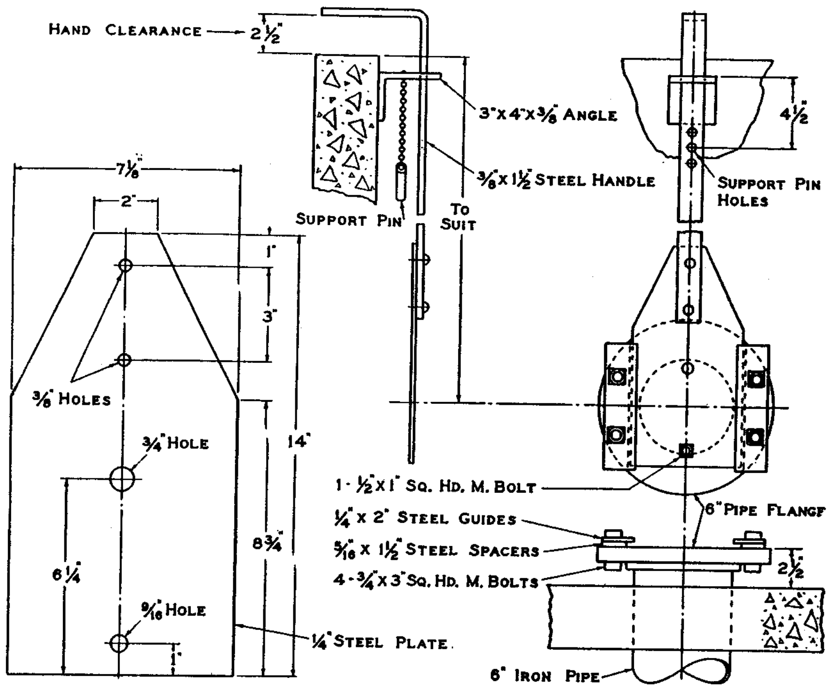

Figure 11.—Slide valve for flushing pipe from the H_B stilling well.

made of eighth-inch steel plate, cut to dimension as shown, with a long handle extending up to the top of the wall. Insert the slide gate into the guides and then fix a short stub bolt through the lower hole in the slide. This bolt head will then come in contact with the bottom edge of the inside of the pipe and stop the gate in its proper position, and will, in like manner, prevent the gate from being withdrawn from the guides. When this slide valve is in normal position, the three-quarter-inch hole is near the top side of the pipe opening and is intended to damp down the pulsations caused by the roughness of the water in the throat of the flume. If sediment is deposited in the 6-inch pipeline, it will occupy the lowest portion leaving some space at the top for the communication of the water pressure.

Gage House and Recording Instrument

The gage house built over the stilling wells is not indispensable as a shelter for the instrument, but it is a useful addition. Experience shows that the convenience afforded by providing a suitable shelter warrants its cost. As shown in the several illustra-

tions of large flumes, the gage houses are built of drop siding, with a shingle or metal roof, hard pine floor, 4-light windows and a well-painted exterior, and are of neat appearance. Some have been finished inside with paneled wallboard, and each one has a built-in cabinet over the gage wells on which the recording instrument is mounted. The height of the top of the cabinet above the crest should be sufficient to prevent the counterweight from striking the top of the float when the maximum stage or depth of water in the flume is reached. For a range of 5 feet in depth the base of the instrument should be not less than 10 feet higher than the crest of the flume. In general, the height above the crest should be somewhat more than twice the maximum H_A gage height. The plane of the front side of this cabinet agrees approximately with the center line through the two gage wells. The remaining area of the top of these wells is covered by a trap door, hinged at the edge so that the opened door will lie flat on the floor of the house, disclosing, within easy reach, a handwheel on an extended stem for operating the 6-inch gate valve on the steel diaphragm, and also the handle of the slide gate. The ladder into the wells should be located on the wall or across the corner near the trap-door opening. The front side of the cabinet should be provided with two doors, hinged at the sides and equipped with a cupboard latch. When these doors and the trap door are open, enough light enters the wells to permit making observations.

A single-head recording instrument is satisfactory for all installations where the submergence will not exceed 80 percent at any time. Under this condition only the H_A gage need be read to determine the discharge. Several types of commercial recorders are available for single head installations. The recorder should have sufficient range to measure the greatest depth expected through the flume. Recorders with a 7-day clock are to be preferred because they do not require daily inspection and rewinding. The recorder should be equipped with a well-made clock and it should preferably be installed inside the recorder cylinder because this is the most effective means for protecting it from dust. Registers with large floats are most satisfactory because they are more sensitive to changes in the water level.

If the submergence is expected to exceed 80 percent, a double-head recorder will be required because under these conditions both the H_A and the H_B gage readings are required to determine the discharge. Double-head recorders satisfactory for service on irrigation canals are manufactured by only a few companies. They are rather expensive and for this reason should be carefully chosen to be sure that a satisfactory instrument is purchased. The clock and other parts of the instrument should conform to the same specifications as those for the single-head recorder.

The double-head recording instrument shown in figure 12 was designed for use in connection with Parshall flumes of large size. This instrument included gage-height indicators for the H_A and H_B heads in addition to the recorder cylinder. A dozen or more of these instruments have been installed and they have given long and satisfactory service. It was hoped that the manufacture and distribution of this instrument would be taken over by one of the instrument companies specializing in this field but to date no company has been willing to manufacture it.

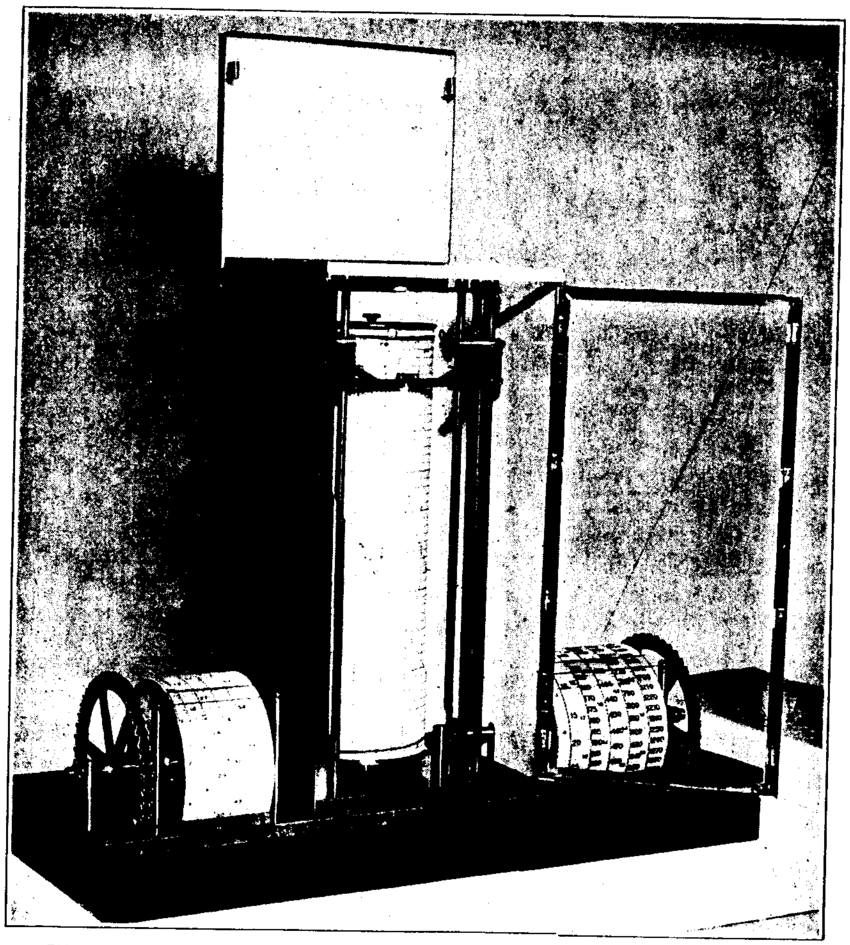

Figure 12.—Double-head recording and indicating instrument for use in connection with Parshall Flumes of large size.

The mounting and setting of the recording instrument requir no expert mechanical skill. By carefully determining the mea crest elevation, using an engineer's level and rod, a referenc point, or bench mark, is set over each well. The elevation o these marks above the mean elevation of the crest is calculate to 0.001 foot and posted at each point. A special weighted hoo gage attached to a light-weight steel tape, graduated to 0.01 foot is used to determine the vertical distance between the water sur face and the fixed reference points (figure 10). To use the hook gage plumb bob, attach it to the ring of the steel tape and lowe it into the water in the well until the point is submerged. Care fully raise until the point just appears, and then read tape at th reference point. This tape reading will, of course, be the distanc to the zero point of the tape. To this must be added the distance A, from the point of the hook to the zero point of the tape. Th sum is the distance from the reference point to the water surface and this sum subtracted from the elevation of the reference poin will be the actual effective head. The reading on the instrumen is observed at the same time that the hook-gage reading is taken the resulting difference indicating the error in the instrumen reading.

In setting the recording instrument for the first time, a ma- terial error may be expected. By moving the chain or tape on the drive wheel, large corrections may be made until a fair agreement is attained. Several hook-gage and instrument readings should next be taken simultaneously. The difference between the means of these observations will indicate the extent of the correction which must be made by adjusting the lock nut attachment at the float. The accuracy with which the instrument is recording the depths should be checked from time to time by means of the hook- gage plumb bob.

Free-Flow Discharge

The free-flow discharge through the Parshall measuring flume for all sizes is defined as that condition of flow where the degree of submergence does not retard or resist the rate of dis- charge. As the water passes through the throat section, it may assume two different and distinct stages; first, where the velocity below the flume is high and the stream flattens out and conforms very closely with the dip at the downstream end of the throat sec- tion; second, where the depth of water in the channel downstream from the structure is such as to cause a hydraulic jump or stand- ing wave to form in the lower portion of the throat. As the de- gree of submergence becomes greater, the standing wave moves upstream in the throat until it becomes "drowned" and the rate of flow is retarded. For all conditions of flow up to this limiting degree of submergence, the rate of discharge is unrestricted, constant and fixed; hence, owing to the application of a definite law of flow, this range is called "free-flow." For very small flumes, such as the 3- to 9-inch sizes, this limiting degree of submergence is approximately 50 percent, while for the 10- to 50-foot flumes the practical limit is about 80 percent.

The free-flow discharge formula for small flumes (1- to 8-foot size)[8],

$$Q = 4WH_A^{1.522W^{0.026}}$$

when extended to large structures is found to give a discharge in excess of the actual flow. In developing the general discharge formula for the large flumes, a more simplified expression has been found to be applicable to flumes ranging in size from 8 to 40 feet. This general discharge formula is

$$Q = (3.6875W + 2.5)\ H_A^{1.6}$$

where Q is the rate of discharge in second feet, W, the throat width in feet, and H_A, the upper gage in feet. The free-flow discharge computed by this formula for an 8-foot flume differs by less than 1 percent from the general expression applicable to the smaller flumes.

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

[8] "Measuring Water in Irrigation Channels with Parshall Flumes and Small Weirs," by R. L. Parshall, USDA, Soil Conservation Service Circ. 843.

TABLE II

FREE-FLOW DISCHARGE 10-FOOT PARSHALL MEASURING FLUME

FORMULA $Q = 39.38\ H_A^{1.6}$

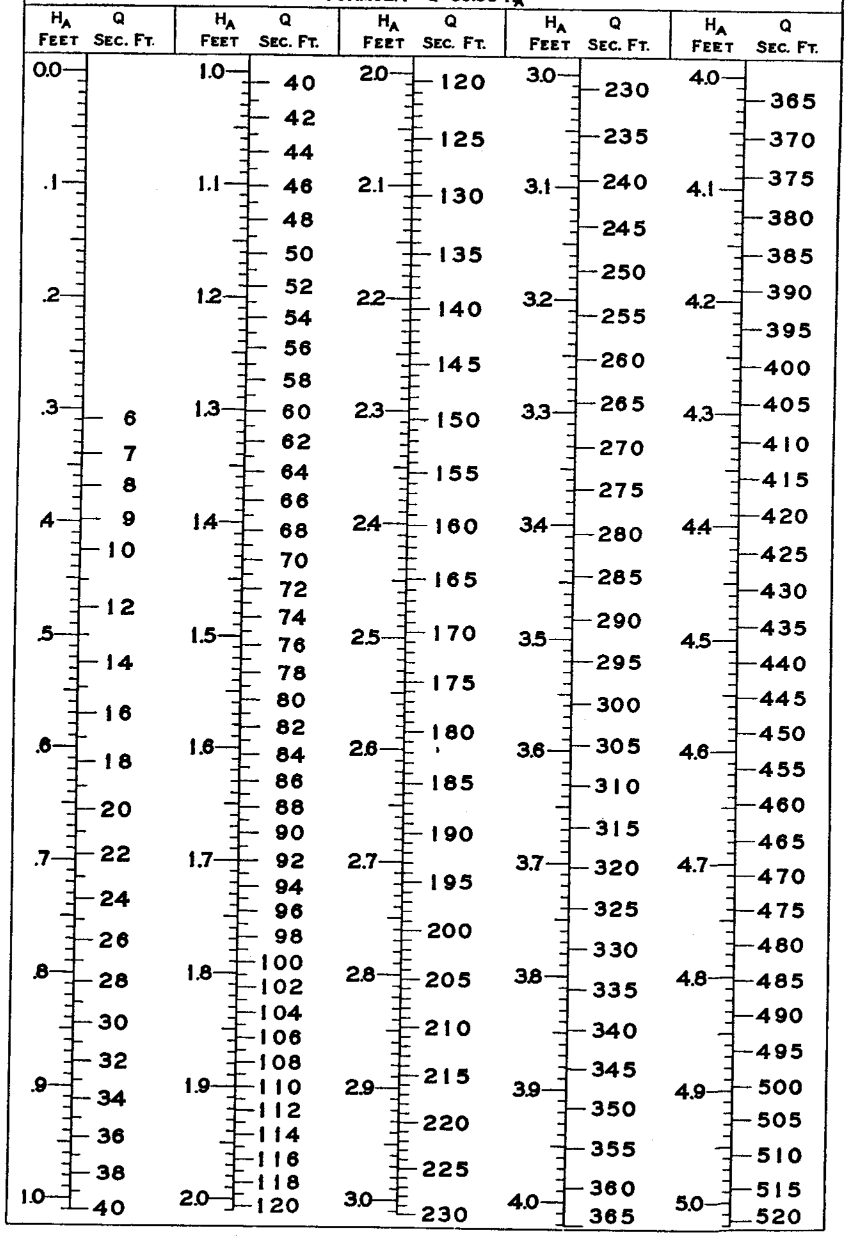

TABLE III
FREE-FLOW DISCHARGE 12-FOOT PARSHALL MEASURING FLUME
FORMULA $Q=46.75\ H_A^{1.6}$

H_A Feet	Q Sec. Ft.
0.0, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1.0	8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48
1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0	48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142
2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0	142, 144, 146, 148, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270
3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0	270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335, 340, 345, 350, 355, 360, 365, 370, 375, 380, 385, 390, 395, 400, 405, 410, 415, 420, 425, 430
4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0	430, 435, 440, 445, 450, 455, 460, 465, 470, 475, 480, 485, 490, 495, 500, 505, 510, 515, 520, 525, 530, 535, 540, 545, 550, 555, 560, 565, 570, 575, 580, 585, 590, 595, 600, 605, 610, 615

TABLE IV
FREE-FLOW DISCHARGE 15-FOOT PARSHALL MEASURING FLUME
FORMULA $Q=57.81\ H_A^{1.6}$

H_A Feet	Q Sec. Ft.
0.0, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1.0	8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0	58, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175
2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0	175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335
3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0	335, 340, 345, 350, 355, 360, 365, 370, 375, 380, 385, 390, 395, 400, 405, 410, 415, 420, 425, 430, 435, 440, 445, 450, 455, 460, 465, 470, 475, 480, 485, 490, 495, 500, 505, 510, 515, 520, 525, 530
4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0	530, 535, 540, 545, 550, 555, 560, 565, 570, 575, 580, 585, 590, 595, 600, 605, 610, 615, 620, 625, 630, 635, 640, 645, 650, 655, 660, 665, 670, 675, 680, 685, 690, 695, 700, 705, 710, 715, 720, 725, 730, 735, 740, 745, 750, 755, 760
5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0	760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000, 1010, 1020

TABLE V
FREE-FLOW DISCHARGE 20-FOOT PARSHALL MEASURING FLUME
FORMULA $Q = 76.25\ H_A^{1.6}$

H_A Feet	Q Sec. Ft.
0.0, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1.0	10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75
1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0	75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230
2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0	230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335, 340, 345, 350, 355, 360, 365, 370, 375, 380, 385, 390, 395, 400, 405, 410, 415, 420, 425, 430, 435, 440, 445
3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0	445, 450, 455, 460, 465, 470, 475, 480, 485, 490, 495, 500, 505, 510, 515, 520, 525, 530, 535, 540, 545, 550, 555, 560, 565, 570, 575, 580, 585, 590, 595, 600, 605, 610, 615, 620, 625, 630, 635, 640, 645, 650, 655, 660, 665, 670, 675, 680, 685, 690, 695, 700
4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0	700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000
5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0	1000, 1010, 1020, 1030, 1040, 1050, 1060, 1070, 1080, 1090, 1100, 1110, 1120, 1130, 1140, 1150, 1160, 1170, 1180, 1190, 1200, 1210, 1220, 1230, 1240, 1250, 1260, 1270, 1280, 1290, 1300, 1310, 1320, 1330, 1340

TABLE VI
FREE-FLOW DISCHARGE 25-FOOT PARSHALL MEASURING FLUME
FORMULA $Q = 94.69\ H_A^{1.6}$

H_A Feet	Q Sec. Ft.
0.0, 1, .2, 3, .4, .5, .6, .7, .8, .9, 1.0	15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95
1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0	95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290
2.0, 2.1, 22, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0	290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540, 550
3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0	550, 560, 570, 580, 590, 600, 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870
4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0	870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000, 1010, 1020, 1030, 1040, 1050, 1060, 1070, 1080, 1090, 1100, 1110, 1120, 1130, 1140, 1150, 1160, 1170, 1180, 1190, 1200, 1210, 1220, 1230, 1240, 1250
5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0	1250, 1260, 1270, 1280, 1290, 1300, 1310, 1320, 1330, 1340, 1350, 1360, 1370, 1380, 1490, 1400, 1410, 1420, 1430, 1440, 1450, 1460, 1470, 1480, 1490, 1500, 1510, 1520, 1530, 1540, 1550, 1560, 1570, 1580, 1590, 1600, 1610, 1620, 1630, 1640, 1650, 1660, 1670

TABLE VII
FREE-FLOW DISCHARGE 30-FOOT PARSHALL MEASURING FLUME
FORMULA $Q=113.13\ H_A^{1.6}$

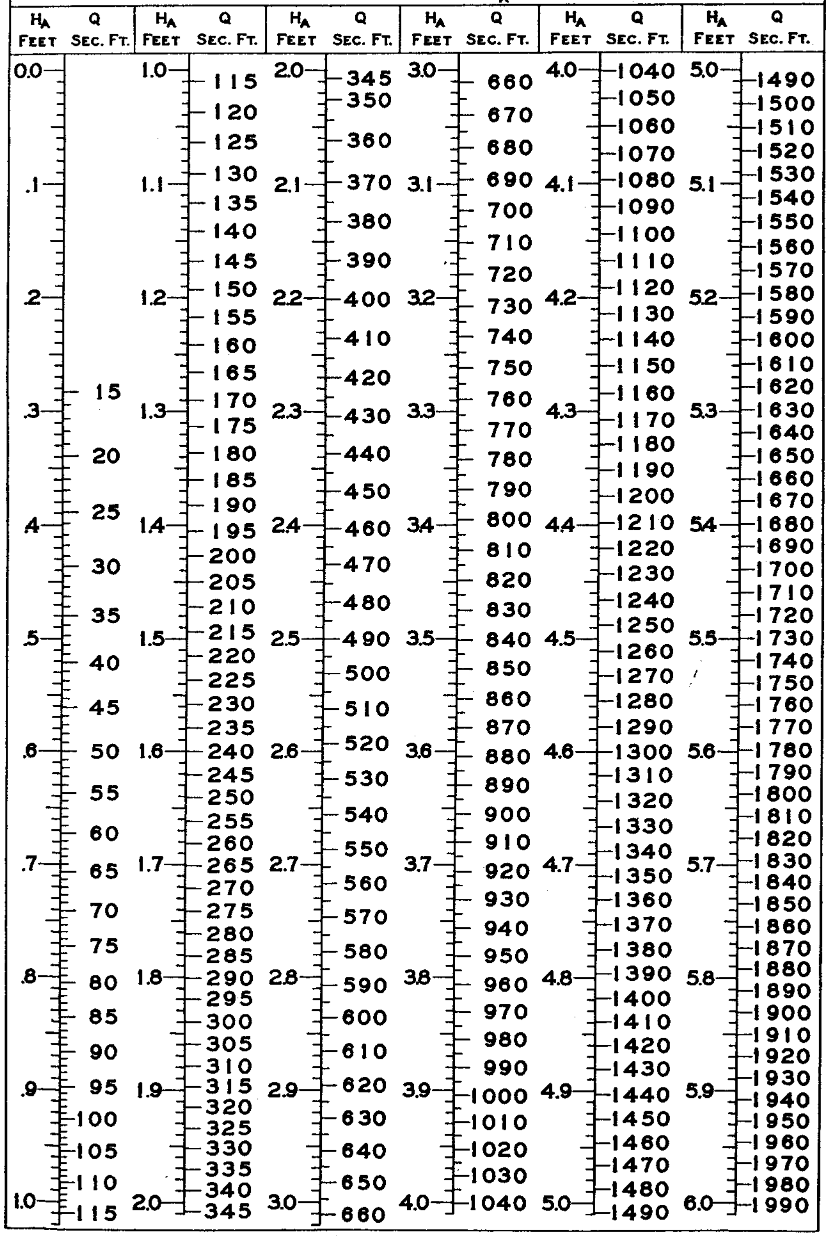

TABLE VIII
FREE-FLOW DISCHARGE 40-FOOT PARSHALL MEASURING FLUME
FORMULA $Q=150.00\ H_A^{1.6}$

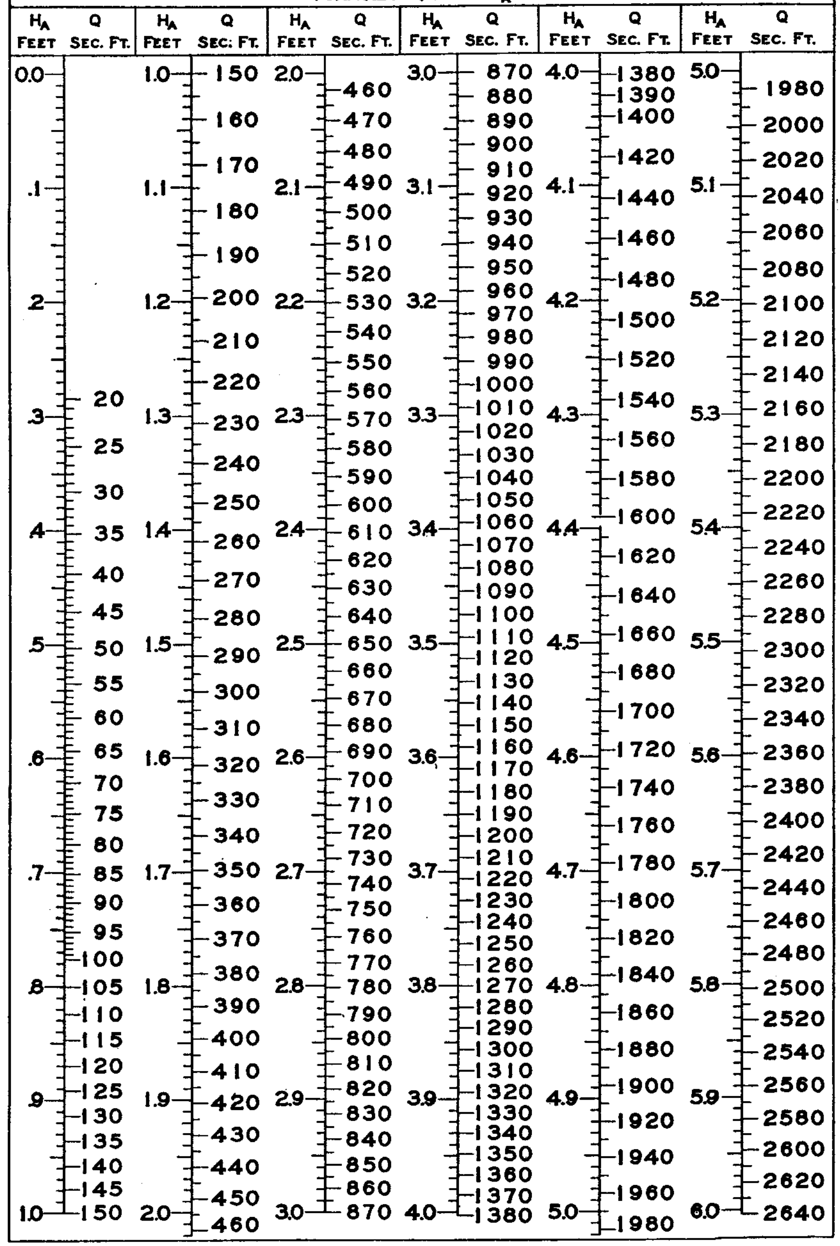

TABLE IX
FREE-FLOW DISCHARGE 50-FOOT PARSHALL MEASURING FLUME
FORMULA $Q = 186.88\ H_A^{1.6}$

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

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

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

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

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

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

Submerged Flow

Submerged flow is defined as that condition of flow where the water in the diverging section of the flume rises to a level where it retards the flow in the converging section. For the small-sized flumes, the free-flow condition of discharge is very desirable, because only one gage height or depth is involved in determining the rate of flow. Here the exit velocities are relatively high, but as the quantity of water is not great, the resulting effect of erosion is easily controlled and of small amount. For the large flumes, where 500 or 1,000 second-feet are being discharged under a condition of free flow, the matter of erosion due to the higher velocities, particularly in soft materials, presents a problem. In general, where the banks and bottoms of the down-stream section of the channel would be subject to considerable cutting, it is the better practice to set the larger structures so that a submerged condition of flow will result for the higher discharges. For submerged flow, where there is no hydraulic jump, both the upper-gage and the throat-gage heights must be considered in the determination of the rate of flow.

To determine the rate of submerged flow, the ratio H_B to H_A is expressed as the percentage or degree of submergence. Figure 13 is a correction diagram showing the amount in second-feet to be deducted for each 10 feet of crest from the free-flow discharge for that particular value of H_A. At the left, vertically, are given the values of the upper head, H_A, in feet. Crossing the diagram diagonally are straight lines indicating the ratio H_B/H_A, the degree of submergence, and along the base of the diagram is the correction in second-feet. The following tabulation gives the multiplying factor for correcting the indicated value from the diagram for the various sizes of flumes:

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

To illustrate the use of the correction diagram, let it be required to determine the discharge through a 20-foot Parshall measuring flume, where the upper head, H_A, is 3.25 feet and the H_B, or lower head, is 3.06 feet. The ratio 3.06/3.25 is 0.941. From the diagram find the value of H_A at 3.25 feet, vertically, along the left-hand side. Next move horizontally to the right to the diagonal line 94; then, by estimation, advance one-tenth of the

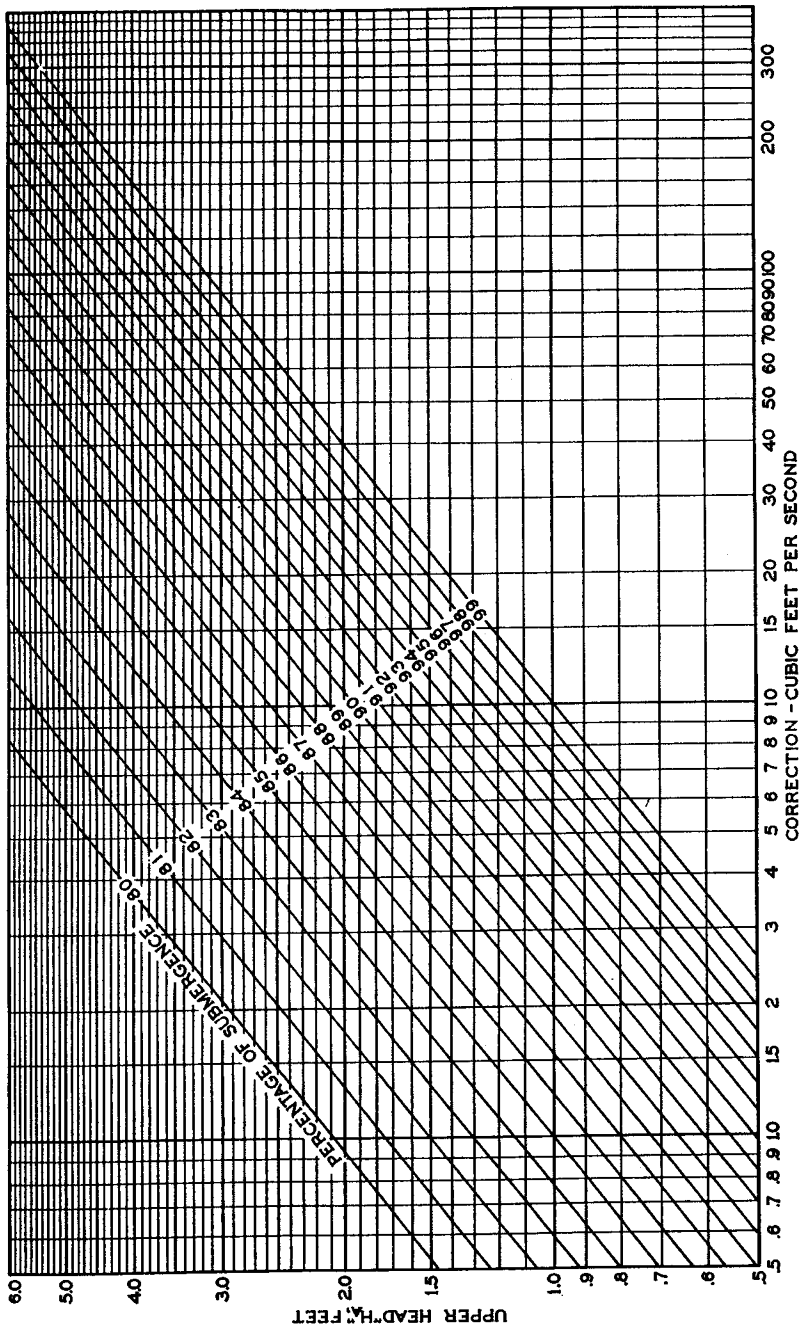

Figure 13.—Diagram for determining the correction in second-feet per 10 feet of crest for submerged-flow discharge.

distance between the lines 94 and 95. Vertically below this point, a correction of 56 second-feet is indicated. From table V, the free-flow discharge through a 20-foot flume with an upper head, H_A, of 3.25 feet is found to be approximately 503 second-feet. The submerged flow, then, is 503—2×56, or 391 second-feet. The correction is determined in the same manner for submerged flow through other sizes of flumes. For a 10-foot flume, the correction is as shown by the diagram; for the 12-foot flume the correction as indicated by the diagram is to be multiplied by 1.2 before subtracting from the free-flow rate of discharge.

Loss of Head through Flume

In the design and setting of the large flumes, it is frequently necessary to know, within reasonable limits, the total loss of head through the structure. It not infrequently happens that it is quite important to predetermine the high-water line in the channel upstream from the flume before installation. The diagram shown in figure 14 will be found useful in making the final selec-

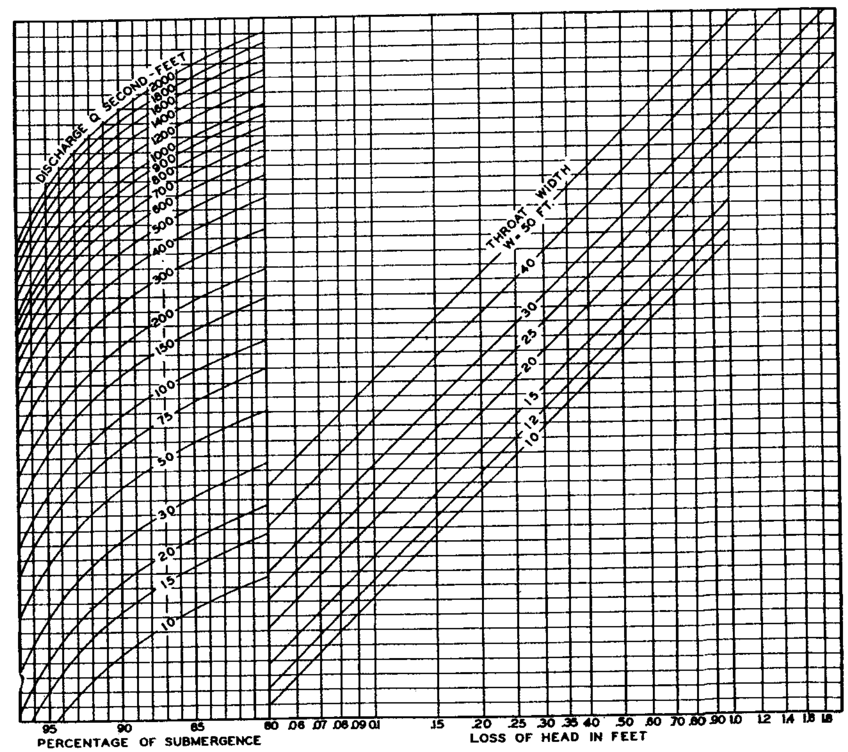

Figure 14.—Diagram for determining the total loss of head through Large Parshall Measuring Flumes.

tion of the size of flume which is to meet the requirements as to capacity, loss of head, degree of submergence, and channel freeboard.

The use of this diagram is best shown by example. Let it be required to determine the loss of head through a 30-foot flume when discharging 1,000 second-feet at a submergence where the ratio of the gage heights, H_B/H_A, is 95 percent. At the left-hand side of the diagram will be found vertical lines, equally spaced, representing the ratio H_B/H_A. On the line 95, move vertically until the discharge curve 1,000 is reached. At this point move horizontally to the right until an intersection is made with the diagonal line marked W=30. Now move vertically downward to the base of the diagram, where the loss of head is found to be 0.39 foot. Likewise, let it be required to determine the loss of head where 100 second-feet is to be measured through a 10-foot flume at a submergence of 80 percent. Making use of the diagram, as in the previous case, the total loss of head is found to be 0.54 foot.

Comparison of Observed to Computed Discharge

Current-meter discharge measurements have been made in flumes ranging in size from 10 to 40 feet for both free-flow and submerged conditions to determine how closely the measured and the computed discharges agree. The current-meter gagings referred to have, in every instance, been made near the upper end of the converging section of the flume. The accelerating velocity of the water in this part of the flume tends to eliminate the eddies and cross currents. This results more or less in a state of streamline flow and gives very good gaging conditions.

The mean deviation between the measured and computed discharges, as determined from 118 observations made by various hydrographers using different current meters and methods of gaging, with the head H_A observed both by the use of staff gage on wall of flume, and in stilling well, is about + 0.5 percent. This result, however, is not to be interpreted as showing that the formula is inaccurate, for the probable error of individual current-meter measurements, even when made by experienced operators, is from 2 to 3 percent.

Summary

Parshall measuring flumes have been found accurate enough to meet practical irrigation requirements under conditions where sand and silt had given trouble in the old type of rating flume.

The range of capacity of the measuring flume extends from less than 0.1 second-foot for the 3-inch flume to more than 2,000 second-feet for the 40-foot flume.

The successful operation of the flume depends largely upon the correct setting of the elevation of the crest above the grade of the channel, and on precise construction to correct dimensions. It is recommended that these flumes be built in straight canal sections.

Large flows can be measured with the Parshall flume with a relatively small loss of head.

A practical and efficient flushing system has been provided for cleaning the H_A and H_B gage wells for flumes operating under severe sand and silt conditions.

A special recording and indicating instrument has been designed for operation in connection with the large Parshall measuring flume.

This type of flume will measure irrigation water supplies efficiently and accurately. It is rapidly replacing the ordinary rating flume.