UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LABORATORY INVESTIGATION OF A CLAUSEN-PIERCE WEIR GAGE

Hydraulic Laboratory Report No. 209

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

SEPTEMBER 10, 1946

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
September 10, 1946

Laboratory Report No. 209
Hydraulic Laboratory
Compiled by: C. V. Adkins
Reviewed by: H. M. Martin
J. N. Bradley

Subject: Laboratory investigation of a Clausen-Pierce Universal Weir Gage.

The problem. Early in 1945 the design department submitted to the laboratory a drawing of a lateral turnout which was to pass flows up to and including 5 second-feet. The flow through this turnout was to be controlled by an orifice gate. The laboratory was asked to build a model of the structure and investigate the use of various measuring devices for determining the flow through the lateral.

Most practical methods of measuring the flow had been tried and found to be unsuccessful in one way or another when attention was called to the Clausen-Pierce Universal Weir Gage. It was requested that the laboratory obtain one of these gages and investigate the possibilities of using it to measure flow through the orifice turnouts. Should the gage perform as indicated by the company, it would be ideal for the lateral turnout measurements.

Summary. A 6-foot weir gage was obtained from a field project for testing in the laboratory. The test program consisted of only a few runs on each of several types of weirs under both free-flow and submerged conditions. Several fully suppressed weirs 44.75 inches wide and of various heights were tested. The crests of these weirs were 2 inches wide. Later, the weirs were shortened to 2 feet. This change caused end contractions which were eliminated by placing 2- by 2-inch pieces on the upstream faces of the weirs parallel to the sides of the notches and back 1.5 inches as shown in Sketch 1B, Page 6. Elimination of the end contractions was necessary since the weir gage was calibrated for

fully suppressed weirs. Next a test was made on a 2-foot fully suppressed weir with a crest consisting of a piece of 12-gage galvanized iron set 4 feet above the channel floor.

In every test the discharges recorded by the weir gage were higher than those recorded by the laboratory venturi meters. The maximum deviation was 19.7 percent. There was no definite pattern of error in the series of tests. Some tests consisted of reading the gage several times for the same discharge. It was shown that one man reading the same discharge over the same weir attained an accuracy of only 2 percent in repeated observations. The brief data indicates that greater accuracy is obtainable with a free-flowing weir or with a very definite drop in water surface across the crest of a submerged weir.

The weir gage was badly worn and battered, a condition which might possibly cause the large error in readings. Therefore it was returned to the project and testing delayed until a new 4-foot gage was obtained from the Clausen-Pierce Company.

Tests with the new gage were made in a channel 5 feet wide. The same types of weirs were tested as with the other gage except that no tests were made on the weir of 12-gage metal mentioned above. In addition, two weirs 5 feet wide with crest widths of 3-5/8 inches were tested. In almost every run the discharge recorded by the gage was less than that recorded by the laboratory venturi meters. The maximum deviation was 10.8 percent. Generally speaking, the readings which were most accurate and those which were high were obtained on free-flowing weirs, or on weirs having a definite drop in water surface across the crest.

The data obtained by the laboratory is not complete and should not be taken as conclusive. However, the erratic readings and magnitude of error indicated by this data was sufficient to warrant the recommendation that these gages not be leased for water measurement on this project without further study. It was also recommended that a more complete and exhaustive test program with these gages be carried out by this laboratory at some future date.

By the general nature of the calibration of the Clausen-Pierce Weir Gage it is seen to be impractical for accurate use on such a wide variety of weirs as may be expected on irrigation-water distribution systems. It is reasonable to expect that a weir gage of this type calibrated on a particular type or style of weir, submerged or free-flowing, would be accurate for any weir of that style, shape and setting. However, the degree of submergence, water-surface drop, contractions, approach conditions, including velocity, etc., affect the calibration; therefore the gage is not as widely applicable as is sometimes believed.

Principle of the Clausen-Pierce Weir Gage. Messrs. Clausen and Pierce first developed a rule for measuring water over a free-flowing weir.1/ The inventors worked on the theory that the velocity head might be transformed into static head by introducing an obstruction into the stream at the crest and observing the height to which the water would climb the face. They figured that this should give the theoretical head in the basic free-weir formula, $Q = CLH\sqrt{2gH}$, which would only need modification by introduction of the value for the coefficient of discharge C, to give the correct flow. Knowing the value of Q, and H, they were able to determine the value of C, which applied. The upstream face of the rule was graduated to read the discharge corresponding to the particular heads for 1 inch of length of weir crest. This simplicity made it possible for a ditch rider to determine accurately the deliveries of water over free-flowing weirs by holding the rule vertically on the crest and reading the highest wetted graduation on its face. This number, multiplied by the width of the weir is the discharge in the unit graduated on the rod. The rule was calibrated to give most accurate results with Cippoletti or fully suppressed weirs.

In the Salt River Valley the submerged weir is far more common than the free-flowing weir. This led Clausen and Pierce to develop what is

---

1/Lippincott, J. B., "Hydraulic Measuring Stick," Western Construction News, Volume 4, 1929, Page 424.

known as the "double weir gage" to be used on either type of weir. They worked on the basis that the discharge over a submerged weir is composed of two parts, the portion above the level of the downstream surface of the water being regarded as a free-flowing weir and the portion below that level as a submerged orifice. To arrive at the discharge of a submerged weir, both the upstream and the downstream heads must be determined. The method of obtaining the upstream head had already been solved in the "single gage." The remaining problem involved discoving a method of determining the downstream head and a way of holding the rod on the crest with the zero graduation at the level of the lower head. The final solution consisted of a plain glass manometer tube attached to the back of the rod, Figure 1. It had a hole slightly less than 1/16 inch in diameter in the bottom closed by a needle valve with its stem extending up through the tube and projecting through the top to form a convenient handle. A second member was added to the "single rule" to form an extension rod similar to a Philadelphia leveling rod. The manometer is attached to the metal slides which form a part of the front section and hold it to the back section. This permits the manometer to be lowered or raised while the back section is held stationary on the crest. A sliding vernier scale is attached to the manometer for setting the water level in the tube. On the back section of the rod, adjacent to the vernier scale, is the "C" scale on which is read the downstream head of a submerged weir. The zero of the "C" scale is the foot of the rod as is also the zero of the "A" and "B" scales. On the front section of the rod, adjacent to the "C" scale, is a vernier for setting the zero of the front section at the level of the downstream head.

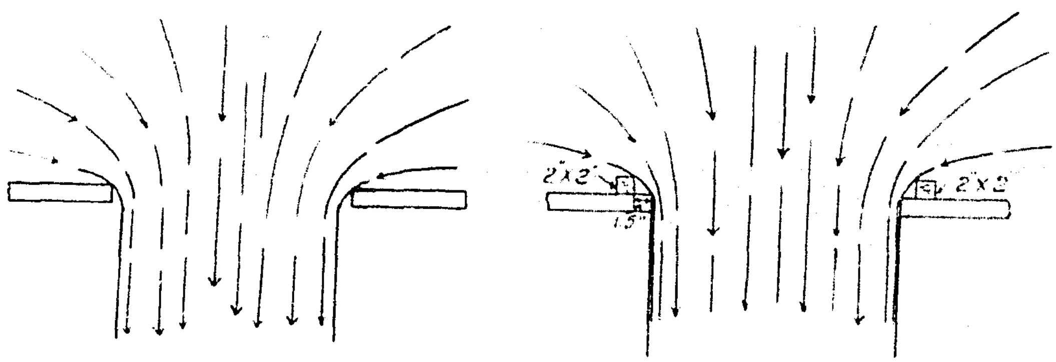
The theoretical formula, $Q = CA\sqrt{2gH}$, with a suitable coefficient C, gives the discharge of the orifice corresponding to the same head determined graphically by the weir gage. A satisfactory coefficient was determined by experiment, and a second scale graduated on the upstream face of the rod by the side of the free-flowing weir scale, or "A" scale. The second scale, or "B" scale gives the discharge for each square inch of submerged orifice. The back head or "C" scale reading gives the height of the orifice. This is multiplied by the number read at the highest wash on the orifice scale to obtain the discharge of the submerged orifice for each lineal inch of weir crest. This discharge added to the discharge per lineal inch of the free-flowing weir and the sum multiplied by the length of the weir gives the total discharge.

Operation of the gage on free-flowing weirs. There are a few simple precautions to be observed to obtain accuracy on a free-flowing weir, according to the instructions:

1. The discharge must be free. That is, there must be a clear drop from the crest to the surface of the water below.
2. Air must have free access under the falling sheet of water.
3. The weir crest should be practically level and the face substantially vertical.
4. The weir should be at right angles to the flow of the water.
5. In the choice of a weir site, whether free-flowing or submerged, the location should be on a straight-away and sufficiently far from gates, checks, or other structures creating wave action, to assure a reasonably smooth approach at the weir.

The company states, in their sales literature, that an elaborate weir structure is not required for using this gage. The lip on the crest of the weir need be only slightly above the bottom of the channel, and the length of the crest should be practically equal to the bottom width of the channel. A wide latitude is allowable in the choice of a weir crest, which may be either 1-, 2-, or 3-inch material, whichever is most convenient. This is true of either a free-flowing or a submerged weir. Provided the rod is held on the center of the crest of either a free-flowing or a submerged weir, a little variation from level in the crest or plumbness on the face of the weir is negligible. It is important to appreciate this, as it removes any uncertainty which might be felt as to the accuracy of measurements made in a crude structure or by means of rough flash boards set in an existing structure.

According to J. B. Lippincott,[1] an immediate temporary decrease in the rate of flow results from introducing the rule into the stream and, especially in a long channel, some time will be required for the back-water curve to become stabilized and for the original rate of flow to be re-established. This is true for either type of weir. In practice, however, it was found that whatever inacuracy may exist due to this condition, the selection of the coefficient C in the formula made it possible to get measurements so close to the indications of the control used, that the difference was not measureable. When the width of the weir was reduced, the readings would naturally be somwhat high, but even at a width of 2 feet or under, the error was less than 5 percent. It was discovered that a contracted weir could be easily converted to a suppressed weir by nailing 2- by 2-inch strips on the upstream face of the weir, parallel to the sides of the notch and set back about 2 inches. Then the vein of water will be made to start its contraction before reaching the edge of the weir notch and the edge of the stream will then pass through the notch normal to it and without any decrease in section, as shown on Sketch 1, Page 6.



A – Contracted Jet

B – Suppressed Jet

SKETCH I

1/ Ibid, Page 3.

A definite determination of the height of splash against the rod may be obtained by wetting the face of the rod and throwing dry dust against it. When held vertically on the weir crest, free-flowing or submerged, the gage will be washed clean to a sharp line indicating the highest surge of water. The reading should be taken precisely at this line to obtain the correct result. This entirely eliminates the personal equation. The reading on the "A" scale is the discharge per lineal inch of free-flowing weir in the units graduated on the gage. Front and side views of the gage are shown in Figure 1. An illustration of the use of the gage on a free-flowing weir is shown in Figure 2.

Operation of the gage on submerged weirs. All but the first two precautions mentioned under free-flowing weirs apply to the submerged weir. In determining the flow over a submerged weir, the first operation is to obtain the submergence or back head. The glass tube on the back of the rod is filled with water by holding it under the surface with the needle valve open. The valve is then closed and the rod held on the weir crest, facing upstream, as shown in Figure 3, with the front section of the rod raised until the bottom of the tube is just below the surface on the downstream side of the weir. The needle valve is opened and after the water has attained a constant level in the manometer tube, the valve is again closed. The water will then stand in the tube at the height of the downstream head, giving the amount of submergence of the weir. The zero of the sliding vernier is then set at the level of the water in the tube and a reading made on the "C" scale. In the setting shown in Figure 3, the reading is 6.36, which is the back head in inches.

For the second operation, the front section of the rod is raised and clamped with the foot at the reading on the "C" scale obtained in operation one, Figure 4. The rod is again held on the weir crest and the readings of the "A" and "B" scales recorded. The scales are read the same as was described above for the free-flowing weir. The "A" scale reading in this example is 0.50 and is the discharge per lineal inch of crest for the free-flowing portion of the weir. The reading on the "B" scale is 0.82 and is the coefficient of the submerged orifice part of the weir. This reading is multiplied by the "C" scale reading of 6.36 to obtain 5.22 which is the discharge per lineal inch of the submerged orifice part of the weir. This plus 2.50 gives 7.72 for the total discharge per lineal inch of weir crest. For a 50-inch crest, the total discharge of the weir would be 386 Arizona Miner's Inches for this gage. An Arizona Miner's Inch is equal to one-fortieth of a second-foot.

The Clausen-Pierce literature states that an advantage of the submerged weir as used with the Clausen-Pierce Gage is the ease with which it may be adapted to changing conditions. In large canals, in seasons of low flow and consequent low head, refinement of measurements may be obtained at negligible cost by raising the head on the weir through introduction of temporary boards at the sides to narrow the weir opening. Loss of head due to accumulation of silt or weeds may be quickly compensated for by raising the weir crest enough to give the scant inch difference which is sufficient for the accurate operation of the gage.

Laboratory tests with a 6-foot Clausen-Pierce Weir Gage. The first test was on a fully suppressed weir consisting of a 2- by 6-inch timber, 44-3/4 inches long placed on edge in the bottom of a rectangular channel. All data accumulated in tests made with the weir gage is shown in tables which follow.

TEST 1-1

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	3.82 sf	4.06 sf	0.24 sf	+ 6.0
Submerged	2	3.56 sf	4.02 sf	0.46 sf	+ 11.4
Submerged	3	3.56 sf	3.90 sf	0.34 sf	+ 8.7
Submerged	4	3.56 sf	4.32 sf	0.76 sf	+ 17.6

The small drop in water surface seemed to be responsible for the wide divergence in readings.

The second weir tested was the same as the first except that it consisted of two 2- by 6-inch planks placed one on the other in the same channel. Seven runs were made on this weir.

TEST 1-2

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	3.55 sf	3.88 sf	0.33 sf	+ 8.5
Submerged	2	3.55 sf	3.81 sf	0.26 sf	+ 6.8
Submerged	3	3.55 sf	4.42 sf	0.87 sf	+19.7
Submerged	4	2.75 sf	2.83 sf	0.08 sf	+ 2.8
Submerged	5	3.82 sf	4.02 sf	0.27 sf	+ 5.0
Free-flow	6	3.55 sf	3.69 sf	0.14 sf	+ 3.8
Free-flow	7	3.55 sf	3.78 sf	0.23 sf	+ 6.1

The third weir tested was the same as the second only with a third 2- by 6-inch timber placed on top of the first two. Six runs were made on this weir.

TEST 1-3

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	3.84 sf	4.39 sf	0.55 sf	+13.0
Submerged	2	3.84 sf	4.08 sf	0.24 sf	+ 6.3
Submerged	3	3.84 sf	4.15 sf	0.31 sf	+ 8.1
Submerged	4	3.36 sf	3.57 sf	0.21 sf	+ 6.3
Free-flow	5	3.84 sf	4.06 sf	0.22 sf	+ 5.7
Free-flow	6	3.84 sf	4.02 sf	0.18 sf	+ 4.6

The fourth weir was the same as number three except that the crest length was shortened to two feet. The resulting weir had end contractions which were eliminated by placing two 2- by 2-inch pieces parallel to the edges of the notch and back 1-1/2 inches. Nine runs were made on this weir.

TEST 1-4

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	3.71 sf	4.07 sf	0.36 sf	+ 9.7
Submerged	2	3.71 sf	3.62 sf	0.09 sf	– 2.4
Submerged	3	3.71 sf	3.83 sf	0.12 sf	+ 3.2
Submerged	4	2.09 sf	2.10 sf	0.01 sf	+ 0.5
Submerged	5	1.61 sf	1.73 sf	0.12 sf	+ 6.9
Free-flow	6	3.71 sf	3.82 sf	0.11 sf	+ 2.9
Free-flow	7	3.71 sf	3.78 sf	0.07 sf	+ 1.9
Free-flow	8	3.71 sf	3.75 sf	0.04 sf	+ 1.1
Free-flow	9	1.61 sf	1.69 sf	0.08 sf	+ 4.9

The fifth weir was 2 feet wide and consisted of two 2- by 6-inch timbers placed on edge, one on the other. The end contractions were eliminated as in the case of Weir No. 4. Two runs were made on this weir submerged for a discharge of 1.71 second-feet. In both cases the discharges recorded by the weir gage were high by 7 percent.

The sixth weir was made by placing two 2- by 6-inch timbers in the bottom of a 2-foot rectangular channel. This formed a 2-foot fully suppressed weir on which six runs were made.

TEST 1-6

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	3.85 sf	4.09 sf	0.24 sf	+5.9
Submerged	2	3.85 sf	3.98 sf	0.13 sf	+3.4
Submerged	3	3.85 sf	4.15 sf	0.30 sf	+7.8
Submerged	4	3.85 sf	4.20 sf	0.35 sf	+9.1
Free-flow	5	3.85 sf	3.87 sf	0.02 sf	+0.5
Free-flow	6	3.85 sf	3.98 sf	0.13 sf	+3.4

The seventh weir was 2 feet wide set in a 2-foot rectangular channel. The crest was made of 12-gage iron and was set 4 feet above the bottom of the channel floor. There were 13 runs made on this weir for free-flow conditions only. The discharges recorded with the weir gage in these runs were consistently high but were not erratic. They show that a person cannot read closer than 2 percent in observing the same discharge over the same weir.

TEST 1-7

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Free-flow	1	5.26 sf	5.62 sf	0.36 sf	+ 6.8
Free-flow	2	5.26 sf	5.58 sf	0.32 sf	+ 6.1
Free-flow	3	5.26 sf	5.52 sf	0.26 sf	+ 4.9
Free-flow	4	4.74 sf	4.95 sf	0.19 sf	+ 4.4
Free-flow	5	4.74 sf	5.04 sf	0.30 sf	+ 5.9
Free-flow	6	4.74 sf	5.04 sf	0.30 sf	+ 5.9
Free-flow	7	4.23 sf	4.56 sf	0.34 sf	+ 7.8
Free-flow	8	4.23 sf	4.50 sf	0.27 sf	+ 6.4
Free-flow	9	3.55 sf	3.72 sf	0.17 sf	+ 4.8
Free-flow	10	3.55 sf	3.72 sf	0.17 sf	+ 4.8
Free-flow	11	2.43 sf	2.58 sf	0.15 sf	+ 6.2
Free-flow	12	2.43 sf	2.53 sf	0.10 sf	+ 4.1
Free-flow	13	1.15 sf	1.29 sf	0.14 sf	+12.2

Laboratory tests with a 4-foot Clausen-Pierce Weir Gage. The first weir tested with this gage was made by placing a 3-5/8- by 3-5/8-inch timber across the bottom of a 5-foot channel to form a fully suppressed weir. Ten runs were made with this weir.

TEST 2-1

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	10.40 sf	9.84 sf	0.56 sf	- 5.5
Submerged	2	11.00 sf	9.81 sf	1.19 sf	-10.9
Submerged	3	11.46 sf	12.05 sf	0.59 sf	+ 4.9
Submerged	4	13.26 sf	13.66 sf	0.40 sf	+ 3.0
Submerged	5	12.27 sf	12.65 sf	0.38 sf	+ 3.0
Submerged	6	14.19 sf	14.98 sf	0.79 sf	+ 5.6
Submerged	7	9.72 sf	8.84 sf	0.88 sf	- 9.1
Submerged	8	9.72 sf	9.12 sf	0.60 sf	- 6.2
Submerged	9	10.22 sf	9.27 sf	0.98 sf	- 9.3
Submerged	10	10.22 sf	9.30 sf	0.92 sf	- 9.0

In Runs 3 through 6 the discharges recorded by the weir gage were higher than those indicated by the laboratory venturi meter. There was a standing wave downstream from the weir in these runs, meaning that there was a very definite drop in water surface across the weir. There was little drop in water surface for the low discharges.

The second weir tested with the 4-foot gage consisted of another 3-5/8- by 3-5/8-inch timber placed on top of the weir used in the preceding test and six runs made.

TEST 2-2

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	8.94 sf	9.58 sf	0.64 sf	+ 6.7
Submerged	2	7.22 sf	7.42 sf	0.20 sf	+ 2.7
Submerged	3	10.38 sf	11.00 sf	0.62 sf	+ 5.6
Submerged	4	10.38 sf	10.81 sf	0.43 sf	+ 4.0
Submerged	5	10.38 sf	10.75 sf	0.37 sf	+ 3.4
Free-flow	6	11.84 sf	11.70 sf	0.14 sf	- 1.1

The third weir, 56 inches wide and fully suppressed, consisted of a 5-5/16- by 1-9/16-inch timber placed on edge in the bottom of a rectangular channel. Six runs were made on this weir, two of them with the weir submerged.

TEST 2-3

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	10.43 sf	10.45 sf	0.03 sf	+ 0.2
Submerged	2	9.71 sf	9.20 sf	0.51 sf	- 5.3
Free-flow	3	12.99 sf	12.32 sf	0.67 sf	- 5.0
Free-flow	4	13.69 sf	13.15 sf	0.54 sf	- 4.1
Free-flow	5	12.09 sf	11.62 sf	0.47 sf	- 3.8
Free-flow	6	11.30 sf	11.20 sf	0.10 sf	- 0.9

The fourth weir was the same as the third except that it was 10-5/8 inches above the channel floor. Seven runs were made on this weir, four of which were for submerged conditions.

TEST 2-4

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	9.65 sf	9.65 sf	0.00 sf	0.0
Submerged	2	10.34 sf	9.88 sf	0.46 sf	- 4.4
Submerged	3	11.22 sf	10.36 sf	0.86 sf	- 7.7
Submerged	4	11.99 sf	11.20 sf	0.79 sf	- 6.6
Free-flow	5	8.94 sf	8.40 sf	0.54 sf	- 6.0
Free-flow	6	9.67 sf	8.40 sf	0.85 sf	- 8.8
Free-flow	7	13.82 sf	13.60 sf	0.22 sf	- 1.6

The fifth weir was the same as the fourth except that it was 21-1/4 inches above the channel floor. All four runs were made with a free-flowing weir.

TEST 2-5

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Free-flow	1	9.03 sf	8.12 sf	0.91 sf	-10.0
Free-flow	2	9.72 sf	8.82 sf	0.90 sf	- 9.2
Free-flow	3	10.19 sf	9.38 sf	0.81 sf	- 8.0
Free-flow	4	11.20 sf	10.50 sf	0.70 sf	- 6.3

The sixth weir was 29-7/8 inches wide, set in a 5-foot channel. The crest was 21-1/4 inches high and 1-9/16 inches wide. The end contractions on this weir were eliminated by nailing two 2- by 2-inch strips parallel to the notch and back 1-1/2 inches. Three runs were made on this weir.

TEST 2-6

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	4.37 sf	4.16 sf	0.21 sf	- 4.9
Free-flow	2	5.90 sf	5.53 sf	0.37 sf	- 6.3
Free-flow	3	6.63 sf	6.12 sf	0.51 sf	- 7.7

The seventh weir was the same as the sixth except that it was only 15-15/16 inches above the channel floor. There were six runs made on this weir, two of them for submerged conditions.

TEST 2-7

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	4.65 sf	4.29 sf	0.36 sf	- 7.8
Submerged	2	5.86 sf	5.72 sf	0.14 sf	- 2.4
Free-flow	3	9.19 sf	8.96 sf	0.23 sf	- 2.5
Free-flow	4	10.07 sf	9.54 sf	0.53 sf	- 5.2
Free-flow	5	11.13 sf	10.53 sf	0.60 sf	- 5.4
Free-flow	6	11.27 sf	10.60 sf	0.67 sf	- 6.2

The eighth weir was the same as the sixth and seventh weirs except that the crest was only 10-5/8 inches above the bottom of the channel. Four runs were made, two of them on a submerged weir.

TEST 2-8

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	9.06 sf	8.74 sf	0.32 sf	- 3.6
Submerged	2	10.24 sf	10.30 sf	0.06 sf	+ 0.5
Free-flow	3	12.05 sf	12.17 sf	0.12 sf	+ 1.0
Free-flow	4	13.69 sf	13.22 sf	0.47 sf	- 3.4

The ninth weir was the same as the eighth except that the crest was only 5-5/16 inches above the channel floor. Sixteen runs were made on this weir, nine of them on a free-flowing weir. In Runs 6 and 7, on a submerged weir, there were 10-1/2 inches difference in the water surface elevations above and below the weir.

TEST 2-9

Type of weir	Run	Q by laboratory venturi meter	Q by Clausen-Pierce Weir Gage	Difference	Percent difference
Submerged	1	9.63 sf	9.65 sf	0.02 sf	+ 0.2
Submerged	2	4.43 sf	4.30 sf	0.13 sf	- 2.9
Submerged	3	9.85 sf	10.03 sf	0.18 sf	+ 1.8
Submerged	4	11.35 sf	11.23 sf	0.12 sf	- 1.1
Submerged	5	13.05 sf	12.75 sf	0.30 sf	- 2.2
Submerged	6	16.00 sf	16.15 sf	0.15 sf	+ 1.0
Submerged	7	16.00 sf	16.22 sf	0.22 sf	+ 1.4
Free-flow	8	4.35 sf	3.88 sf	0.47 sf	-10.8
Free-flow	9	9.88 sf	9.56 sf	0.32 sf	- 3.2
Free-flow	10	10.23 sf	9.90 sf	0.33 sf	- 3.2
Free-flow	11	11.25 sf	10.82 sf	0.43 sf	- 3.8
Free-flow	12	11.25 sf	10.97 sf	0.28 sf	- 2.4
Free-flow	13	12.91 sf	12.52 sf	0.39 sf	- 3.0
Free-flow	14	13.65 sf	13.30 sf	0.35 sf	- 2.6
Free-flow	15	15.64 sf	15.50 sf	0.14 sf	- 0.8
Free-flow	16	15.64 sf	15.50 sf	0.14 sf	- 0.8

It will be noticed that all but one of the discharges recorded with the 6-foot gage obtained from the field project were higher than those indicated by the laboratory venturi meter. Of the 62 readings made with the new 4-foot gage, only 16 were high and none of them extremely so. At present this laboratory has no explanation as to why one gage would read high and the other one low, unless the two gages were calibrated under entirely different circumstances. The most accurate readings obtained with the 6-foot gage were on free-flowing weirs or on weirs having a very definite drop in water surface across the crest. The highest accuracy of readings obtained with the new 4-foot gage was about equally divided between the two types of weirs.

The curve shown in Figure 5 is a calibration of the Clausen-Pierce Meter made by Cornell University. The weir from which the data was taken for plotting this curve was sharp-crested and located in an ideal situation. One series of 13 runs made by this laboratory on a 2-foot sharp-crested weir showed only one reading within an accuracy of 4 percent. The Clausen-Pierce literature indicates that accurate readings may be obtained by placing any type of board across the bottom of a natural channel to give a drop in water surface, and that only one reading need be made on such an arrangement. Most of the data compiled by this laboratory points to the fact that any one reading may be inaccurate by several percent. King's Handbook of Hydraulics recommends that, where accuracy is important, the head over a weir should represent the mean of 10 to 20 readings taken at intervals of approximately 30 seconds. These readings are to be made on gages set in stilling-wells.

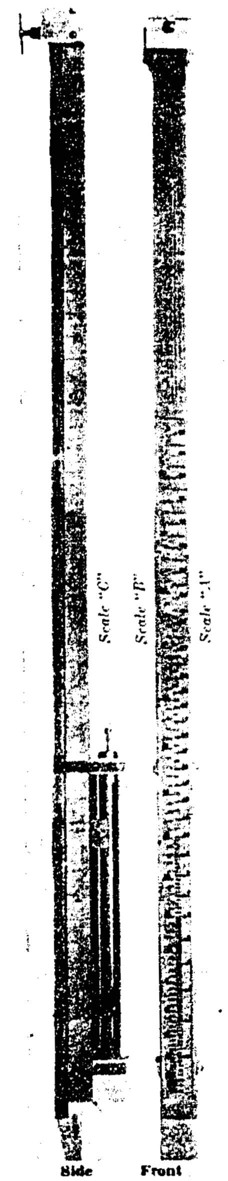
The accuracy of the Clausen-Pierce Gage is supposedly represented by data obtained under ideal conditions on a sharp-crested weir. This type of weirs is not recommended for field use, neither have any results of field tests been presented by the company.

This laboratory conducted its tests in rectangular channels having smooth walls and floors. The weirs were set vertical to the channel floor and at right angles to the direction of flow. The timbers used for weir crests were squared and planed, which the company does not suggest as being necessary. The tests were made under much more ideal conditions than would exist in the field or would be necessary according to the information issued by the company.

In the August 25, 1929, issue of Western Construction News an independent author describes the development and use of the Clausen-Pierce Weir Gage. Therein are three tests listed as conducted by Engineers F. J. O'Hara and T. A. Hayden of the Salt River Valley Water Users' Association. In these tests readings were observed on the free-flow control weir and on weirs of various crest widths and lengths under both free-flow and submerged conditions. These observations were averaged and, fortunately for the gage company, the results obtained were almost identical with the control discharges.

This laboratory does not understand why readings obtained under such variable conditions should be averaged, unless there were several weirs of different types in the canal on which readings could be taken as a check. In the event that more than one reading was taken, it would seem more reasonable to observe several readings on one weir and average them for the final result. It would appear that a better procedure would be to average the submerged weir readings and the free-flow weir readings separately. In this way one would know the general characteristics of the gage for the two types of weirs, and could correct the readings if necessary.

Water has become so valuable in recent years that is must be divided with the highest degree of accuracy. On the basis of the data obtained by this laboratory, the Clausen-Pierce Weir Gage cannot be recommended for water subdivision on Bureau projects without calibration in individual structures. It appears that the gage is not as widely applicable as the company represents it for accurate measurement of water. The gage undoubtedly has a number of distinct advantages and if calibrated and used in individual structures should give results equal in accuracy to other more cumbersome but better recognized methods of measurement.

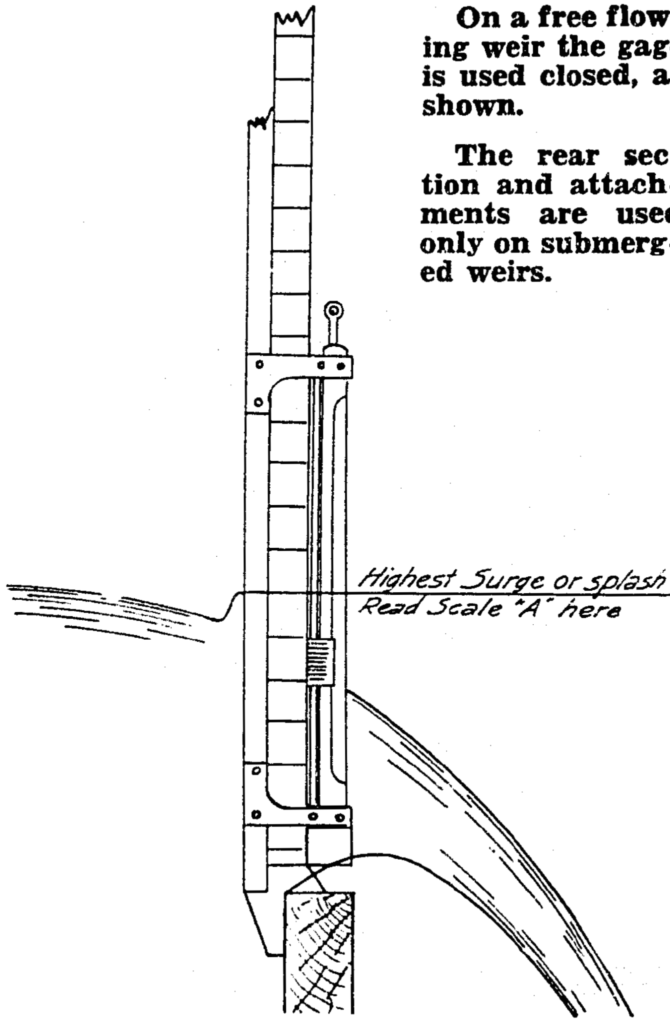


No settings are required and only one scale is read in making measurements over a free flowing weir. The gage is held vertically on the crest of the weir and Scale "A" on the face of the rod (See picture at left) is read at the point of highest run-up or splash against the face. This reading gives the discharge in Sec.-Ft., Miner's inches, gallons per minute or whatever unit is graduated on the rod, for one inch in length of weir crest. This scale reading, multiplied by the length of the crest in inches, is the total discharge.

CLAUSEN-PIERCE UNIVERSAL WEIR GAGE

On a free flowing weir the gage is used closed, as shown.

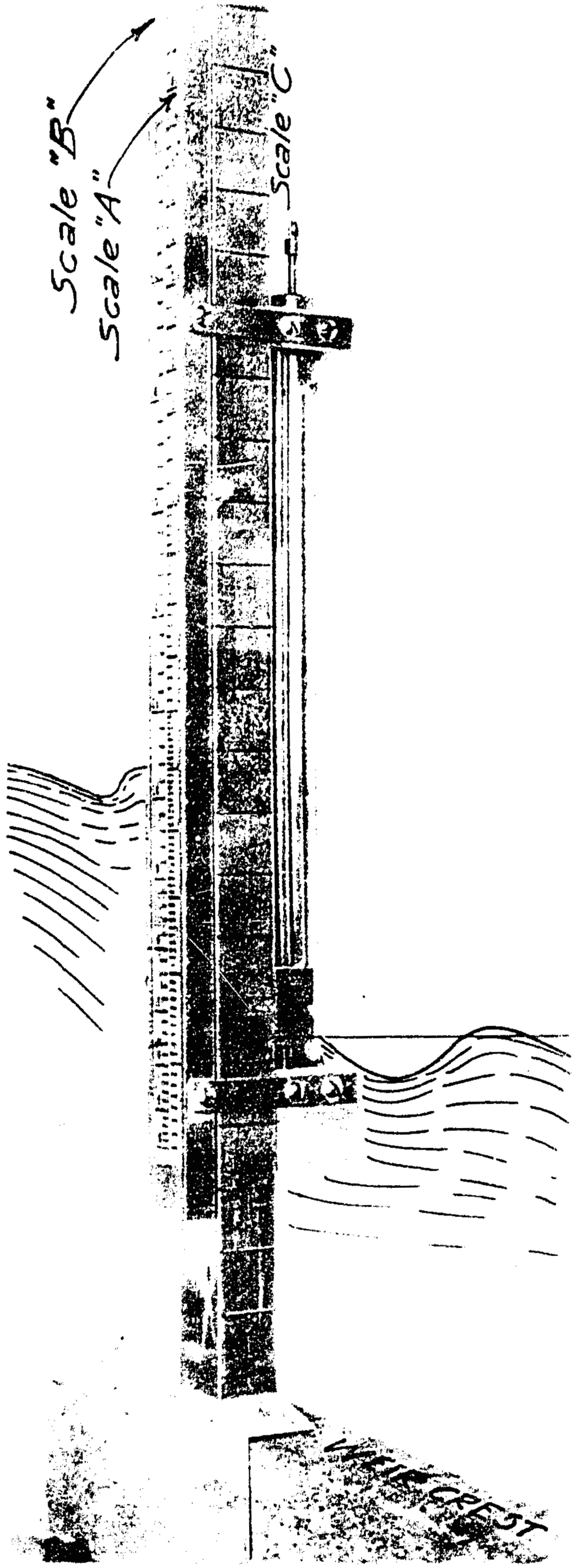
The rear section and attachments are used only on submerged weirs.



Using universal gage on free-flowing weir. The weir-crest in sketch is a 2-inch plank.

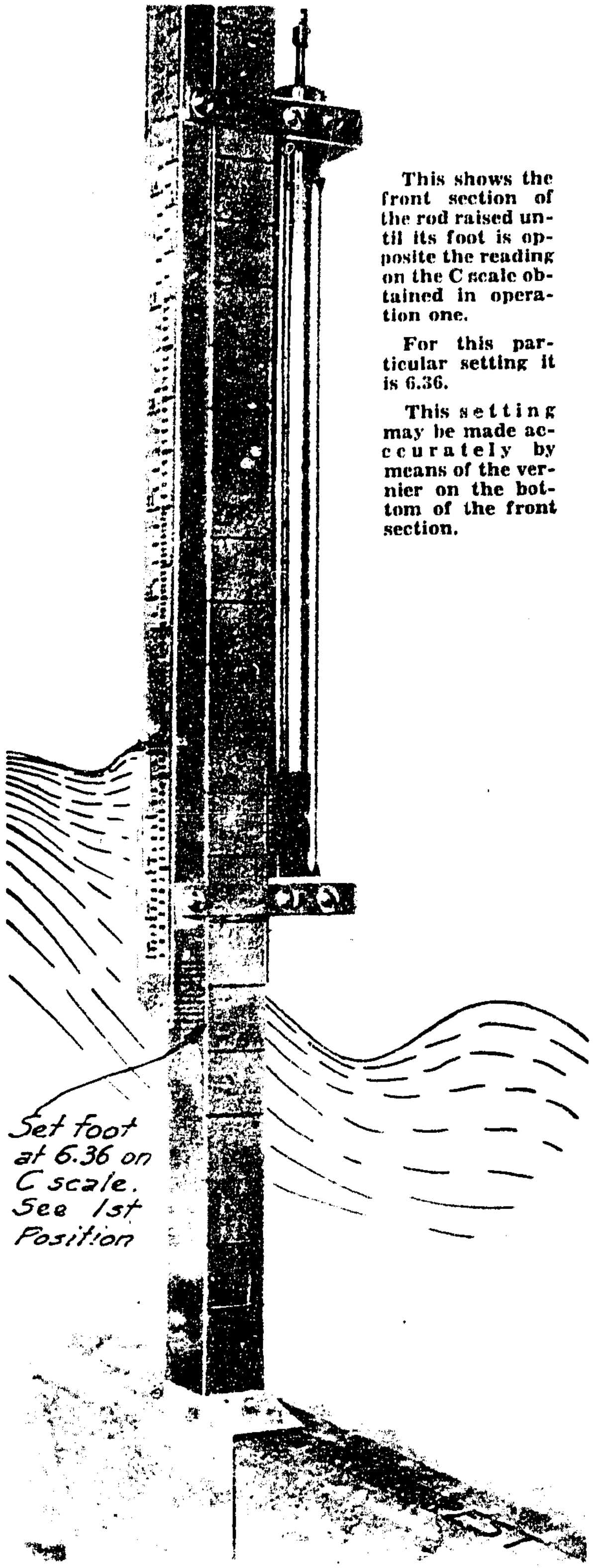
CLAUSEN-PIERCE UNIVERSAL WEIR GAGE

FIGURE 3



Measuring the back head on a submerged weir.

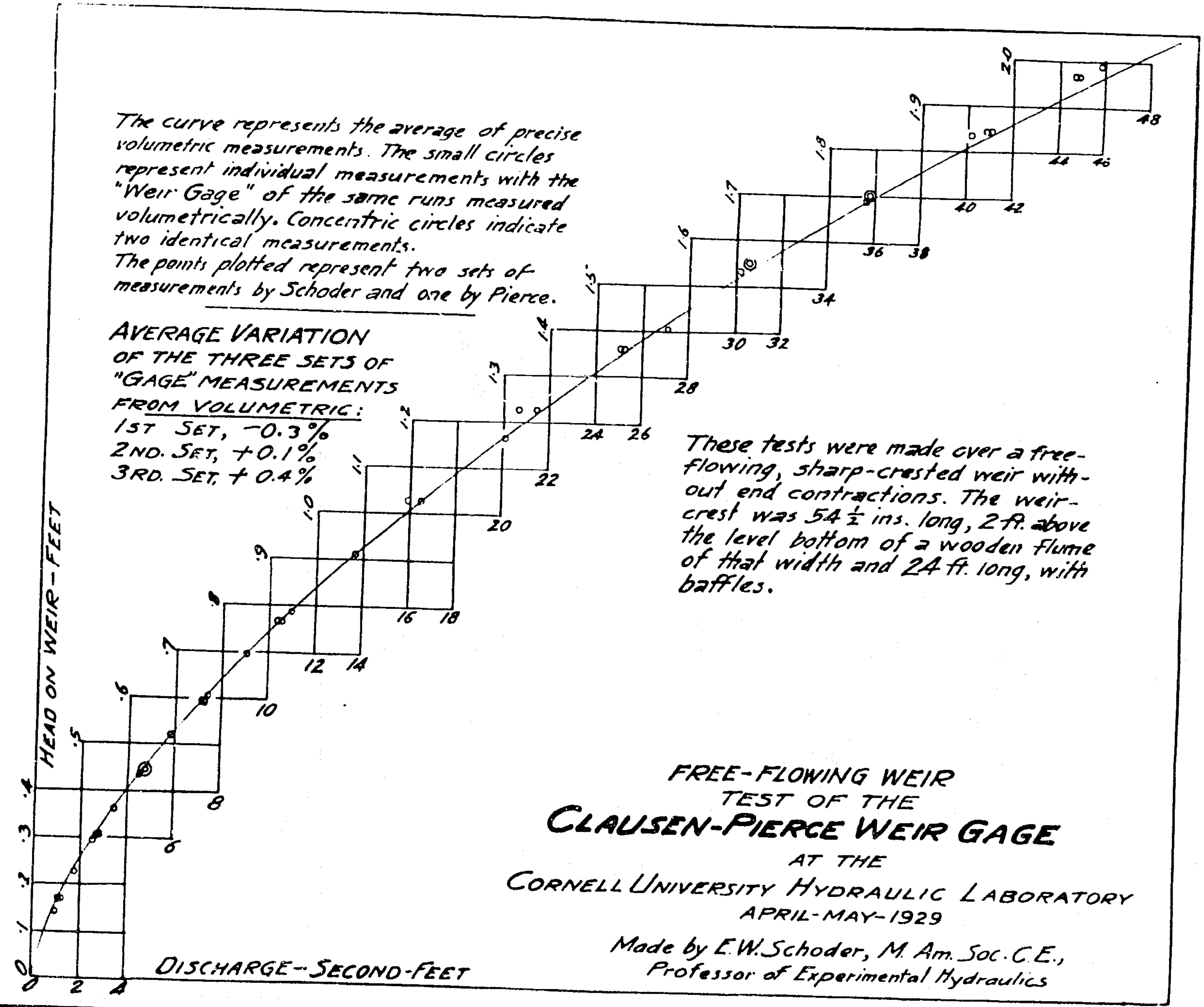
CLAUSEN-PIERCE UNIVERSAL WEIR GAGE



Measuring the discharge over the free-flow portion of a submerged weir.

CLAUSEN-PIERCE UNIVERSAL WEIR GAGE

FIGURE 5



The curve represents the average of precise volumetric measurements. The small circles represent individual measurements with the "Weir Gage" of the same runs measured volumetrically. Concentric circles indicate two identical measurements.
The points plotted represent two sets of measurements by Schoder and one by Pierce.
AVERAGE VARIATION OF THE THREE SETS OF "GAGE" MEASUREMENTS FROM VOLUMETRIC:
1ST SET, −0.3%
2ND. SET, +0.1%
3RD. SET, + 0.4%
These tests were made over a free-flowing, sharp-crested weir without end contractions. The weir-crest was 54 ½ ins. long, 2 ft. above the level bottom of a wooden flume of that width and 24 ft. long, with baffles.
HEAD ON WEIR - FEET
DISCHARGE -- SECOND-FEET
FREE-FLOWING WEIR
TEST OF THE
CLAUSEN-PIERCE WEIR GAGE
AT THE
CORNELL UNIVERSITY HYDRAULIC LABORATORY
APRIL-MAY-1929
Made by E.W. Schoder, M. Am. Soc. C.E.,
Professor of Experimental Hydraulics