Memorandum

Denver, Colorado
April 16, 195[illegible]

To: Chief, Division of Irrigation Operations

Through: Chief, Hydraulic Laboratory and Chief, Division of Engineering Laboratories

From: C. W. Thomas, Head, Hydraulic Investigations Section

Subject: Clausen-Pierce weir rule

In recent months, there has been recurrent discussion, both within the Bureau organization and inquiries from outside agencies, regarding the merits of the Clausen-Pierce weir rule as a device for measuring flowing water. It appears appropriate to review the development of this device and the experience with its use.

The idea of employing some sort of a device to include the head due to velocity of approach to the observed head on a weir is not new. Prior to 1920, Mr. W. G. Steward did considerable work on such a device while working with the Bureau of Reclamation on the Boise Project. On that project a considerable number of weirs were included in the system as measuring devices. As frequently happens, the weir pools became more or less filled with sand, silt, moss, and weeds, thus causing the water to run through a narrow shallow channel to the point where it passed over the weir. In this case, instead of being stilled, the water approaches the weir crest with considerable velocity, and unless a correction is introduced for this velocity of approach, erroneous measurements will result from a reading of the gage commonly placed upstream from the weir or fastened to the weir cutoff structure. During the period from approximately 1910 to 1919, considerable thought was given to this problem by Mr. Steward. He conducted experiments during the season of 1919 to find an easy method by which ditch riders could determine closely the flow over such weirs. The results of these experiments show that, by use of the ordinary enameled weir scale, this could be done if a definite procedure was followed. The procedure outlined by Mr. Steward was to place the scale held in a perpendicular position, on and near the center of the weir crest with the thin edge cutting the water; then suddenly turning the broad side against the flow of water and noting the height to which the water rose on the scale. The discharge given by the weir table for this total head was found to be very nearly accurate.

In 1921, Mr. Steward made another series of tests concurrently with water measurements on the project. During these studies, there was designed a set of five scales mounted on riders and made interchangeable so that they could be operated on a common stand, the lower part of which was also a scale. These scales had different cross sections, namely: straight line, V-shaped, a channel-iron shape, a segment of a large circle, and a segment of a small circle. These scales were used to determine the velocity head of the moving water. The method used was to set the bottom of the shaft on the weir crest with the flat side in line with the water flow. The height at which the water cut the scale was noted. The rider was then moved down until the end was well under water. The position at which the water rose on the base of the scale was noted as before. The actual head on the weir plus the velocity head was thus determined, and by use of this head, the ordinary tables for the weir discharge could be used with a fair degree of accuracy.

Apparently, Mr. Steward took no steps toward patenting the process, his only wish being to make available to the users some simple method of measuring the water through weirs that had been contaminated in the pool portion by weeds, etc. Mr. Steward did conclude that the standard enamel weir scale 2-1/2 inches wide and 18 inches long would be most useful for this purpose. The shape of the other cross sections was such that they could not be used without a staff, and with the staff they were too complicated for general use by the ditch riders. It was found that velocities between 1.5 and 5.5 feet per second could be measured with a fair degree of accuracy by this method. Lower velocities did not give enough change in elevation of water surface for accurate readings, and greater velocities gave too great a variation in the scale readings caused by the slight but rapid changes in the velocity of the water movement.

References to Mr. Steward's work may be found in Bulletin No. 127, dated January 1922, of the University of Idaho Agricultural Experiment Station. The pamphlet is titled "The Measurement of Water, A Handbook for Ditch Riders and Water Users" by W. G. Steward. Another reference may be found in Reclamation Record, June 1921, page 276, title "Easy Method for Determining Discharge over Weirs Having Velocity of Approach" by W. G. Steward and E. H. Coffin. The most complete record of Steward's work is contained in "Report on the Use of Various Forms of Scales for Measuring Velocity of Approach over Weirs and for Making Stream Measurements" by W. G. Steward, Assistant Engineer, Boise Project, Idaho, 1922. (This report is in the Bureau of Reclamation Records in Denver, Communications and Records, File 516, Boise.)

Another early development of a similar type device is reported in Civil Engineering, November 1944, page 475, under the title

"Velocity-Head Rod Calibrated for Measuring Streamflow" by H. G. Wilm and H. C. Storey. In this article the authors state that a dependable, yet cheap and rugged measuring stick, had been developed several years previously, at the San Dimas Experimental Forest in Southern California, to facilitate the calculation of discharges from mountain streams. A description of the device and some tables indicating its accuracy are included in the article. According to the authors, the instrument used by that organization has an accuracy within about plus or minus 2 percent. It is not known whether or not this device was actually developed prior to the work done by Clausen and Pierce. Apparently no patents were applied for on the velocity-head rod, and it was reported for use by the general public.

In regard to the Clausen-Pierce weir rule, the subject of this memorandum, the measuring device is the invention of I. M. Clausen and R. A. Pierce, both of the Salt River Valley Water Users Association. A brief description of the rule, as developed, appeared in Engineering News-Record, Volume 96, No. 21, May 27, 1926, page 850. This description was of the single stick which required a free-flowing weir and was graduated to give most accurate results with Cipolletti or weirs without end contractions. Western Construction News of August 25, 1929, page 424, carries a rather complete description of the weir rule as developed by Mr. Clausen and Mr. Pierce. This article also gives some of the background of the development.

It can be noted from the latter article that the weir rule was developed for definite types of installations. As stated in the article, most of the structures for delivery of water on the project had a standard width of 4 feet. The discharges ranged from 1/2 second-foot to 15 second-feet. The first device evolved was a rod 5 feet long, 1-1/2 inches wide, and 3/4 inch thick, graduated on the upstream face.

It was stated that this rod gave very good results when the 4-foot-wide structure was used. When the width of the weir was reduced, readings were a little high, but even at a width of 2 feet or under, the error was less than 5 percent. On lengths of weir crests greater than 4 feet, the error became almost negligible, as stated in the article.

Early in 1945, the Design Division of the Bureau of Reclamation requested the Hydraulic Laboratory to investigate the uses of various measuring devices for determining the flow through a lateral having a turnout capacity of 5 second-feet. Among the means investigated for measuring the discharge in this turnout was a Clausen-Pierce universal weir gage. The results of these studies are reported in Hydraulic Laboratory Report No. 209 of the Bureau of Reclamation. The conclusion of this report states that "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.

Another reference to use of this device by the Bureau of Reclamation may be found in Bureau of Reclamation Region 3 Chino Valley Project, Arizona, Project Planning Report No. 3-8b.9-0, Appendices, April 1946. Page 55 of this report gives some comparative figures obtained in the Chino Valley Irrigation District with a rented Clausen-Pierce weir stick. The table on this page shows that there is a wide range of variations in the figures. Whether the discrepancies were brought about by errors in the measuring device itself or by improper use is not easily determined.

In regard to the use of the Clausen-Pierce weir rule on Bureau projects, in 1946 there was correspondence between Region 3 and the Denver office regarding rental of a limited number of the weir rules for use on the Gila Project. It is not known whether these rules were actually purchased or leased at that time or not. The subject was again opened in April 1948, and a letter was sent to the Regional Director, Boulder City, Nevada, stating that this office was not in a position to endorse the use of the rule. However, the project may have purchased some of these rules at that time.

It has also been reported that there may be at least one Clausen-Pierce weir rule in use on the Angostura Project in South Dakota. Other than these two possibilities, we have no record of the weir sticks being used on Bureau projects.

When Paul Kaufmann of Israel was in the United States as an FOA observer, he became interested in this measuring device. Upon completion of his field trip, he returned to this office and inquired regarding the address of the company manufacturing these instruments. Apparently, the address given him was incorrect, and he later wrote seeking corrected information. This was supplied at a later date. It is not known whether he has made arrangements to purchase this type of instrument or not.

In a letter of March 22, 1956, the Kings River Water Association at Fresno, California, requested that they be supplied with a discussion of the merits and faults of the Clausen-Pierce weir rule for measuring water with the degree of accuracy comparable to that obtained by a Parshall flume, Venturi tube, or current meter. The reply, dated April 6, 1956, was signed by the Assistant Commissioner and Chief Engineer.

Other verbal inquiries have been received in this office from time to time.

When Sam Larsen returned from a foreign assignment to a position in the Division of Irrigation Operations, he inserted a note in the proposed program, contained in a memorandum from that division and the Canals Branch that the Clausen-Pierce weir rule be made a subject of study in the proposed water measurement program.

It may be noted from the advertising media furnished by the company that the earlier brochures were filled with considerable propaganda concerning the use of the rule. The pictures and narrative indicate that it may be used universally in streams and many other types of structures with a high degree of accuracy. However, the new brochures furnished this office as a result of the inquiries made by Paul Kaufmann emphasize the use of the rule only on standard weir structures of limited width. The new brochure states that the weir rule may be used for accurate measurements in free-flowing weirs, in submerged weirs, and suppressed and contracted weirs, providing the weir structures are more or less standard design and of limited width. It is quite probable that, with this limited use, or, rather, that the use of the instrument limited to these more or less standard structures, may give much better results than those obtained previously.

In summarizing the information available on the Clausen-Pierce weir rule, the following comments are pertinent:

1. As a result of the brief tests made by the Hydraulic

Laboratory of the Bureau of Reclamation early in 1945, the device was not recommended for use in Bureau projects because of the discrepancies found in the tests. One series of tests was made in a rectangular channel 44-3/4 inches wide. The weir sill consisted of a 2- by 6-inch timber turned on edge so that it formed a fully suppressed weir. Four runs were made with this weir submerged. The observations by the weir rule ranged from 6 percent to 17.6 percent greater than the discharge indicated by the laboratory Venturi meter (for a discharge of 3.56 cfs). It was found to be impossible to narrow the divergence of observed values, principally because of the small drop in water surface and the erratic surging of the water surface. With a weir consisting of two 2- by 6-inch timbers placed on edge, one on the other in the same channel, the observed discharge with the rule was from 2.8 to 19.7 percent greater than that indicated by the laboratory Venturi meter for a discharge of 3.5 cfs. Over a weir consisting of three 2- by 6-inch timbers placed on edge in similar fashion in the same channel, the observed discharge with the rule was from 4.5 to 13 percent greater than that indicated by the laboratory Venturi meter at a discharge of 3.84 second-feet. The rule was also used on a 24-inch suppressed 12 gage metal weir discharging under free fall conditions. The observed flow varied from 4.1 to 12.2 percent greater than the Venturi meter indicated for flows over a range of from 1.15 to 5.26 cfs. There was no definite pattern of error with the variation of discharges. These tests indicated that greater accuracy might be obtainable with a free overfall crest or with a very definite and appreciable drop in water surface across the weir than with the submerged condition.

2. The field use of the instrument in the Chino Valley investigations indicates that the rule may be of questionable value as an accurate measuring device.

3. Judging from the information in the brochures, it is possible that the manufacturer now concedes that the rule cannot be used universally but is limited to certain types of structures. This is in accordance with our findings; namely, that, by the general nature of the calibration of the Clausen-Pierce weir rule, it is seen to be impractical for accurate use for such a wide variety of weirs as may be expected on irrigation water distribution works. It is reasonable to expect that a weir gage of the

Clausen-Pierce type calibrated on a particular type or style of weir, submerged or free flowing, would be accurate for any weir of that particular type and setting. However, the degree of submergence, water surface drop, approach conditions, including velocity, contraction, etc., affect the calibration. Therefore, the rule may not have a high degree of accuracy for widely divergent applications.

4. From the available information and without benefit of exhaustive studies, it can only be assumed that the rule should not be accepted as an accurate measuring device. In view of the fact that there appears to be a need for additional work on this type of device, it would seem that Larsen's suggestion that it be included in the water measurement program is in order.

5. I believe that considerably more work must be done on this rule to determine its accuracy. In places, it might be applicable to a considerable portion of our measuring problems. If the rule could be used to determine velocity of approach to a weir and this approach velocity head added to the head as measured at the weir and included in the discharge as determined from the tables, then our measurements could possibly be made more accurate. This, of course, should be verified by further work on the instrument.