A LABORATORY EVALUATION OF FLOW-MEASURING DEVICES FOR USE IN DRAIN TILES

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November 1962 CER62RHB71

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Short Version published
"Evaluating Flow Measuring Devices for Drainage Systems
Ag-Engrng
Oct 1963, p. 557, 560
V. 44, N. 10

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A LABORATORY EVALUATION OF FLOW-MEASURING DEVICES FOR USE IN DRAIN TILES[1]

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INTRODUCTION

A study of the flow in drainage tile at various points within a given tile system may be helpful in analyzing drainage systems and provide useful design information. Soil variability, tile size, depth of tile installation, filter material, irrigation practices and sources of foreign water all may be contributing factors to the amount of water discharging from a given installation. In the case of interceptor tile drains, an analysis of an existing system is difficult since the locations of the major sources of contributing water may be unknown. The inaccessibility of drainage tile for measuring flow at any given point also presents a serious problem.

There are many interesting and excellent instruments for measuring flow in closed conduits flowing full (1, 2, 4, 5, 7). Very few of these instruments are adaptable for measuring flow in drainage tile where there is a free water surface. Many open channel measuring devices (3, 6, 8, 9) are adaptable for measuring tile effluent at the end of the tile system. In an effort to find an economical and

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[1] Contribution from the Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A. and the Colorado Agricultural Experiment Station Cooperating.

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accurate method for obtaining discharge measurements within a drainage system, several instruments were evaluated in the laboratory. The purpose of this paper is to discuss several simple methods for measuring flow in drainage tile where the line is flowing partly full.

Equipment and Procedure

A 6-inch standard lightweight steel pipe, 20 feet long, was set up in the laboratory to simulate a typical reach of tile drainage pipe in the field. The pipe was supported by three screw jacks which were manipulated to produce a desired slope. At 5-foot intervals, slots 2-1/2 x 6 inches were cut in the top of the pipe. Through these slots the flow-measuring instruments were inserted to measure velocity and depth of flow. The instruments were attached to a point gage which was mounted on a traveling overhead dolly as shown in Figure 1.

Figure 1. Laboratory arrangement of test pipe for evaluating flow measuring devices.

The water supply was obtained from a 4-inch turbine pump which discharged through a calibrated venturi meter. The venturi meter was considered accurate down to a flow of 25 gallons per minute. For smaller flows, gravimetric methods were used to determine the discharge through the experimental pipe.

Three instruments were evaluated for accuracy and ease of operation and are shown in Figures 2, 3, and 4. They include:

Figure 2. The pitot-static tube designed for use in drain tile.

Figure 3. The midget current meter and accessories used for measuring flow in experimental pipe. (Photo courtesy of Leupold and Stevens Instruments, Inc., Portland, Oregon.) [1]

[1] Trade names and company names are included for the benefit of the reader and do not infer any endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.

Figure 4. A collapsible 90° "V"-notch weir for measuring flow in drain tiles.

(1) a pitot-static tube[2], (2) a midget current meter[3], and (3) a collapsible 90-degree "V"-notch weir. Since the first two instruments measure the fluid velocity at a point, measurements were taken at three different depths in the vertical profile except when depth of flow was inadequate. Both of these instruments were calibrated in a towing tank before they were used in the experimental pipe. For the pitot tube and current meter, velocity and depth of flow measurements were made for discharges ranging from 11 - 130 gallons per minute and for slopes of 0.1, 0.3 and 0.5 per cent.

In order to obtain another type of instrument for flow measurement purposes, a collapsible 90-degree "V"-notch weir was constructed to conform to the inside diameter of a 6-inch pipe as shown in Figure 4. The discharge was obtained by gravimetric measurements for small flows and by using the venturi meter for large flows while the weir was in position in the test pipe. The depth of water above the weir crest 2-inches upstream from the weir face was measured by a point gage for discharges ranging from 4.5 - 130 gallons per minute and for slopes of 0.3 and 1.4 per cent.

Results and Discussion

Data for the pitot tube and current meter measurements are shown in Figure 5. The measured discharge is plotted against the

Figure 5. Calculated discharge compared with measured discharge using a pitot-static tube and current meter to obtain single velocity measurements.

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[2] Courtesy of the U. S. Salinity Laboratory, Riverside, California.

[3] Courtesy of the U. S. Bureau of Reclamation; Federal Center, Denver, Colorado.

discharge calculated from measured velocity and depth of flow. Since accurate velocity profiles are difficult and impractical to obtain under field conditions, each velocity determination and depth of flow was used to calculate the discharge. Such calculations produce errors which occur when using a single velocity measurement regardless of depth. The relationship to a 1:1 line of actual discharge measurements to calculated values can be seen in Figure 5. The departure one would expect from the actual discharge if a single measurement was taken with either of these instruments is also apparent. For the data shown, the departure of the calculated discharge from the measured discharge may be attributed mostly to variations in velocities with depth. However, some of the departure also may be attributed to errors in measuring depth of flow, since this was measured only over the center line of the pipe. There was no single point in the vertical velocity profile where the average velocity could be consistently determined.

The results of the "V"-notch weir tests are shown in Figure 6. The depth of flow above the weir crest and 2-inches upstream from

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Figure 6. Calibration curve for collapsible 90° "V"-notch weir in a steel pipe for two different pipe slopes.

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the weir face is plotted as a function of discharge. The position of the top of the weir in relation to depth readings is shown on the ordinate in Figure 6. Discharges having depth readings greater than 0.167 feet flowed entirely through the weir "V". The equations relating discharge to the depth of water above the bottom of the "V" are shown in Figure 6. The fact that water flowed over the upper edges of the weir and braces did not seem to affect the slope of the curves shown. For a given depth, an increase in the slope of the pipe increases the discharge because of an increase in the approach velocity. An increase of the pipe slope from 0.3 to 1.4 per cent increased the discharge from 10 to 18 per cent depending upon the value of the depth reading. Tile installations in the field are usually set at slopes considerably less than one per cent, therefore a single calibration curve, such as that shown in Figure 6 for 0.3 per cent, seems justified for field use.

Accuracy in measurement of depth of flow above the weir is important. As an example, using the equation for 0.3 per cent slope, an error of 0.01 feet in measurement of depth in the range of H of 0.15 feet results in an error in flow of approximately 16 per cent. However for a depth of 0.30 feet this same error would result in a discharge difference of only 6 per cent.

CONCLUSIONS

The midget current meter is primarily a laboratory instrument and requires careful handling. Due to the fragile characteristics of the meter, its acceptability as a field instrument for measuring flow in drainage tile is doubtful. The pitot tube, on the other hand, is more rugged in that there are no moving parts and it usually holds its calibration quite well. The major field problem in using the pitot tube is obtaining a manometer reading at the soil surface. A small pump is needed to pump the water from the tile to the manometer. Due to a water column hanging 6 to 8 feet below the manometer, air is readily removed from the water and the lines require frequent reflushing to remove the air.

The weir-type instrument appears to be best suited for field measurement. Once it has been calibrated, it is not seriously affected by slope or flow conditions. Also only a single depth reading is required to obtain the discharge. A disadvantage of the weir instrument is that some time must be allowed for water to come to equilibrium behind the weir. An electrical sounder is a convenient means for obtaining the depth readings for the weir. The weir can be calibrated by measuring the depth directly over the weir crest by passing the sounder through the handle of the weir. The weir can be collapsed for insertion through a minimum opening of 2-1/2-inches. With the weir resting on the bottom of the tile and by pushing down on the handle of the weir, it can be expanded and sealed against the inside wall of the pipe. To collapse the weir in the pipe, a 1-inch lightweight electrical conduit is passed over the handle until it rests on the cross braces of weir, and the handle of the weir is pulled up while the 1-inch pipe is pressed down.

The success of any type of flow-measuring instrument is entirely dependent upon the accessibility of the fluid being considered. For the case of flow in drainage tile, accessibility presents a very serious problem. Hand methods of excavating and exposing a section of the tile are uneconomical and time consuming. A more practical approach to the problem involves designing access wells at the time the tile system is installed. Many existing systems have access wells available for making this type of measurement. However, improper design and installation of access wells in the tile line has resulted in noncircular cross sections at the point of measurement. This makes calculations for the area of flow difficult for the velocity-type instruments and, in the case of the weir, prevents sealing the weir in proper position.

A typical access well for making flow measurements is shown in Figure 4. Access wells should be installed near the junction of two or more tile lines and at other locations along the tile line as indicated by the soil profile and foreign water sources.

FIGURES

Figure

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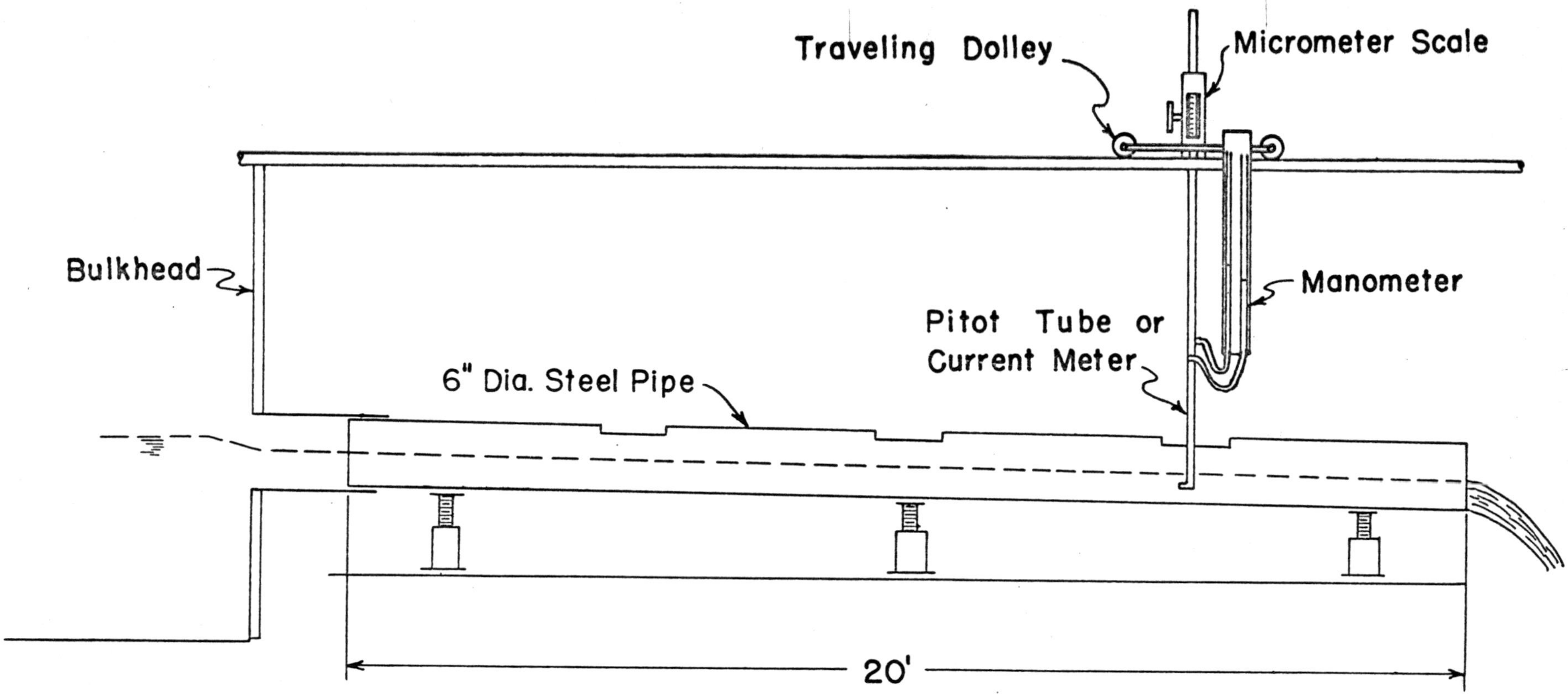


Fig. 1. Laboratory arrangement of test pipe for evaluating flow measuring devices

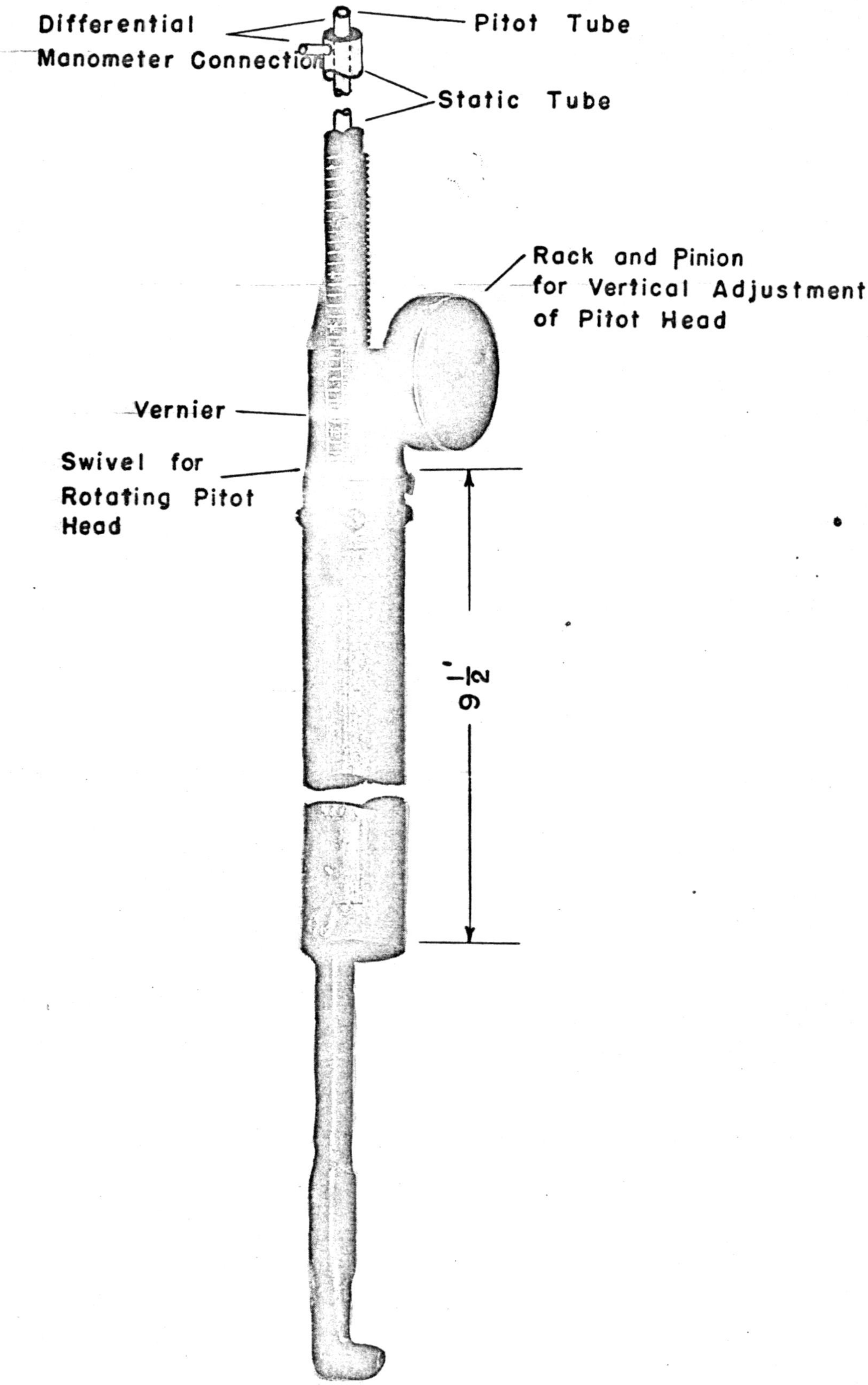


Fig. 2. The pitot-static tube designed for use in drain tile.

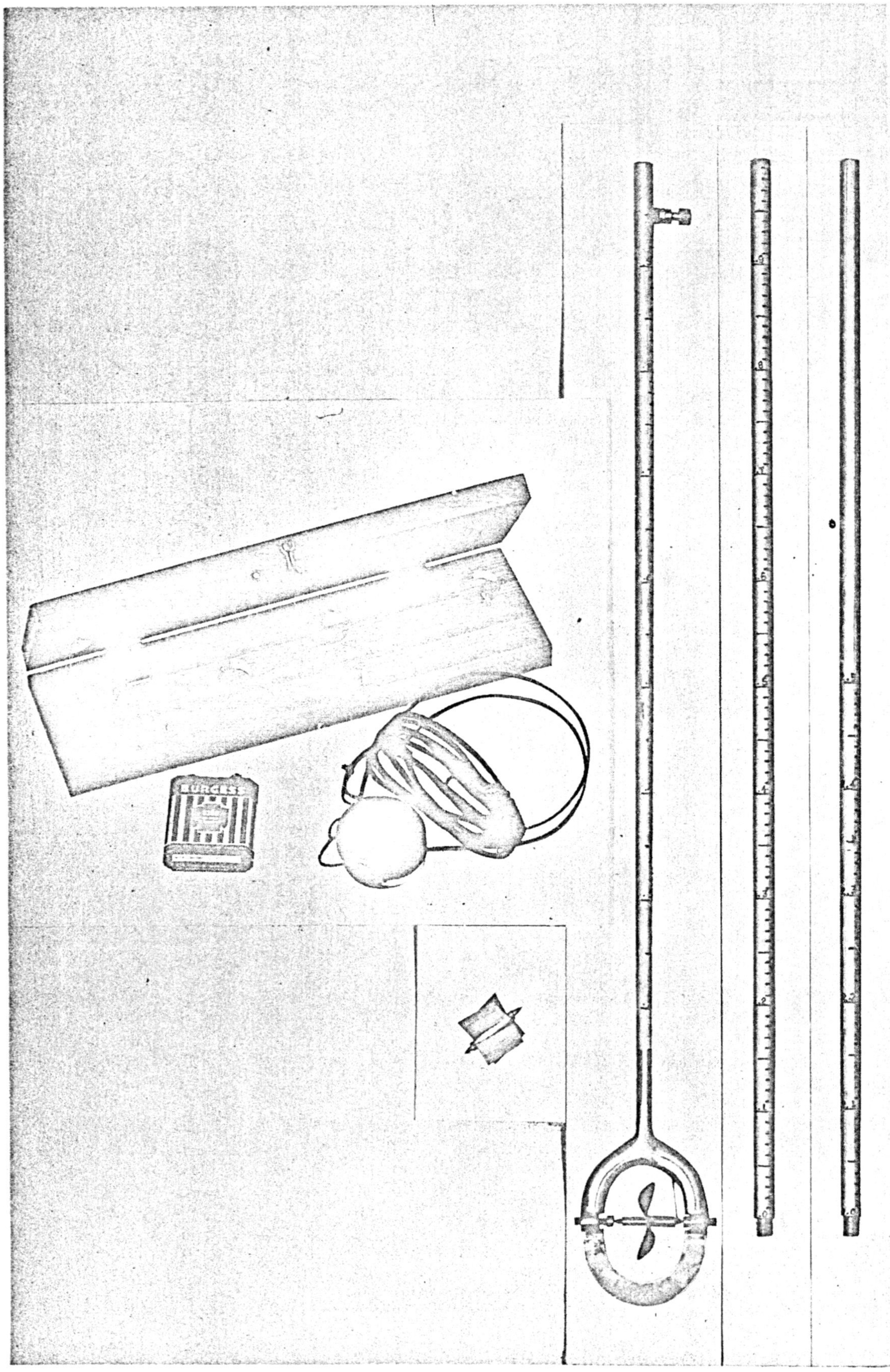


Fig. 3. The midget current meter and accessories used for measuring flow in experimental pipe. (Photo courtesy of Leupold and Stevens Instruments, Inc., Portland, Oregon.)[1]

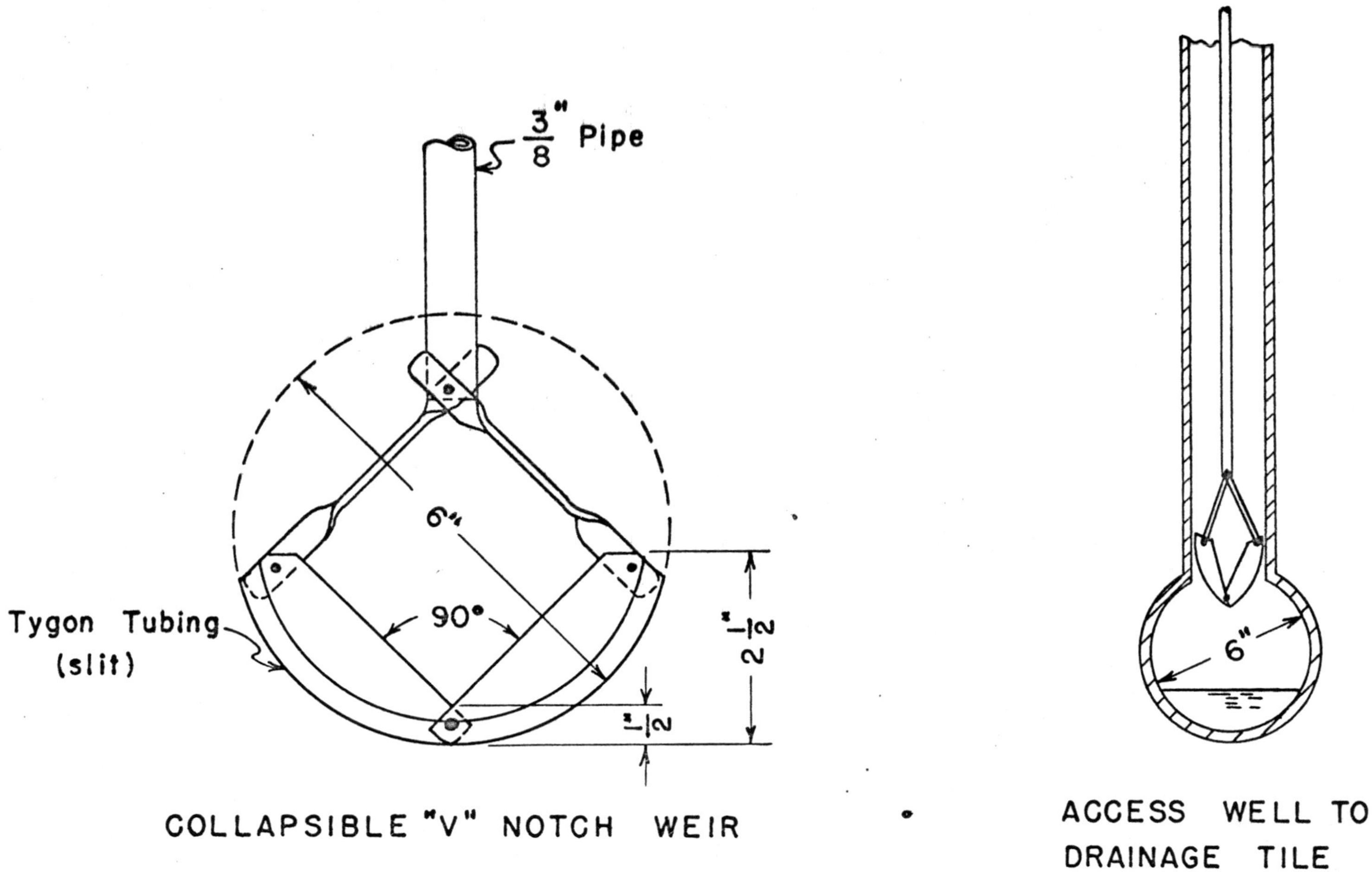
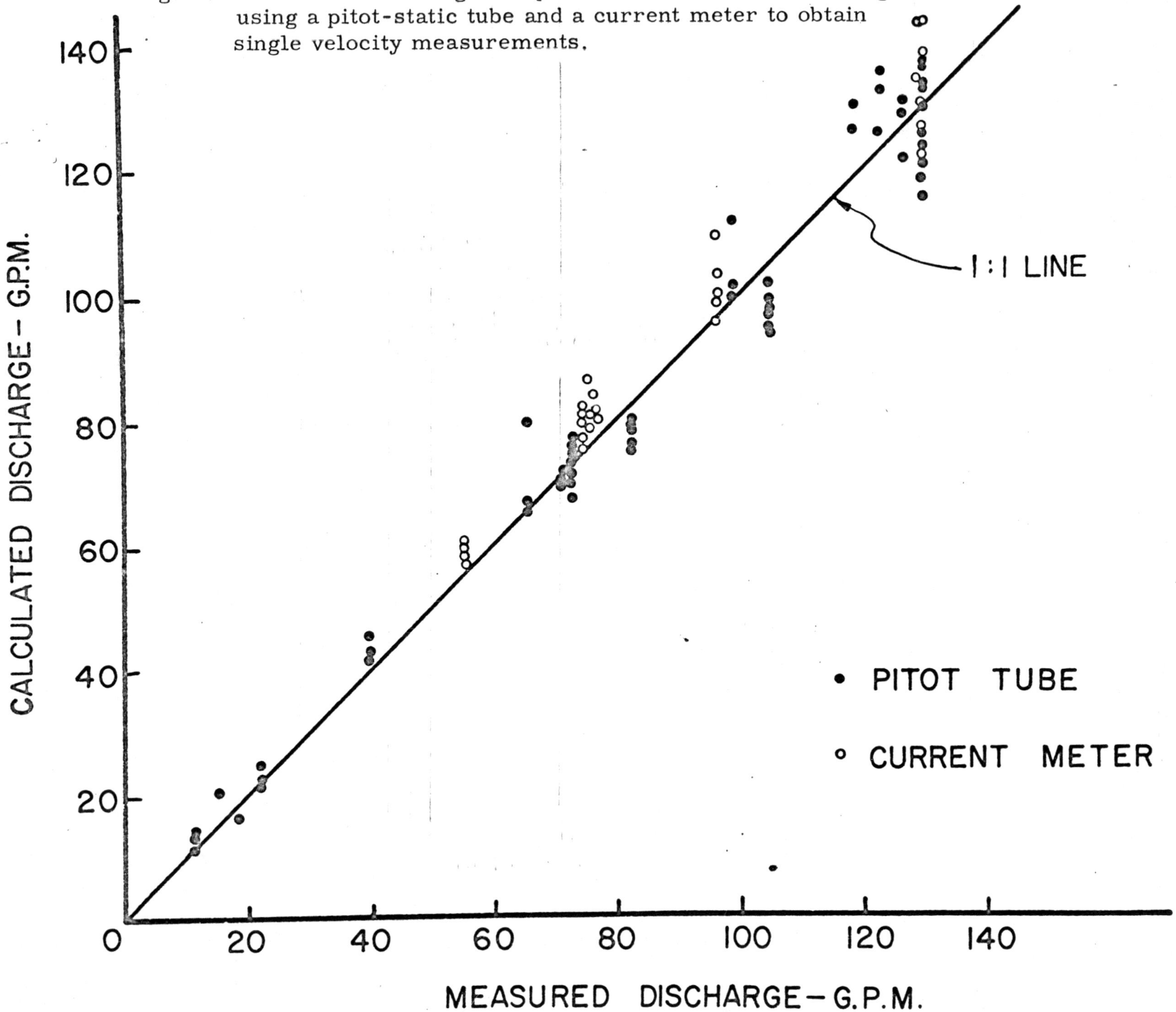


Fig. 4. A collapsible 90° "V" notch weir for measuring flow in drain tiles

Fig. 5. Calculated discharge compared with measured discharge using a pitot-static tube and a current meter to obtain single velocity measurements.



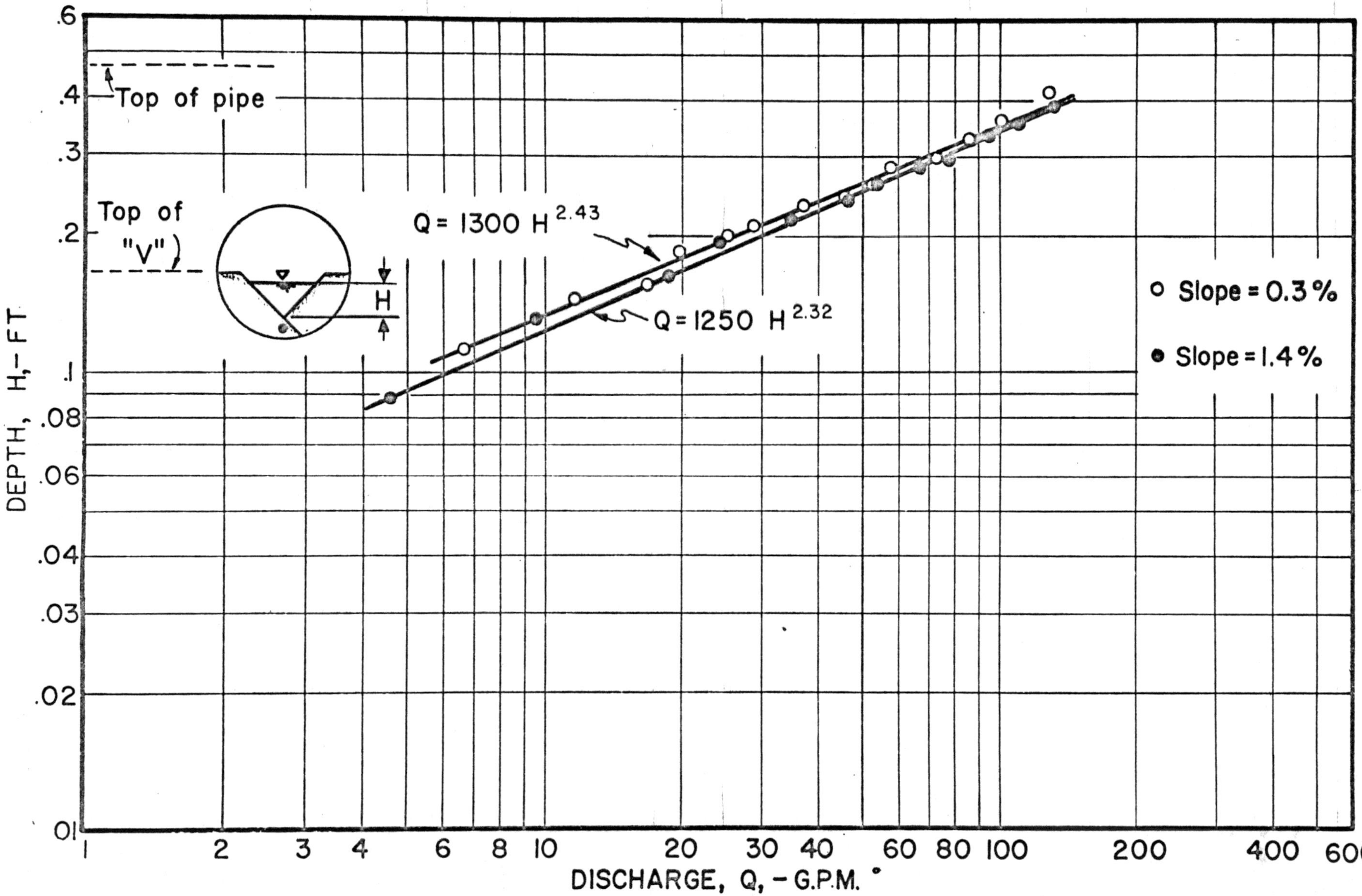


Fig. 6. Calibration curve for collapsible 90° "V" notch weir in a steel pipe for two different pipe slopes.