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Evaluation of Some Irrigation Water Control Devices

RHYS TOVEY

VICTOR I. MYERS

Department of Agricultural Engineering

IDAHO Agricultural Experiment Station

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Information on Field Performance

MOST water control devices can be used advantageously to control irrigation water into furrows on steep land.

Efficient application of water and reduced erosion result when distribution devices are properly used.

Head control devices must be used in conjunction with the distribution systems to assure proper control over furrow discharge.

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Evaluation of Some Irrigation Water Control Devices

RHYS TOVEY and VICTOR I. MYERS*

THE distribution of water into furrows on steep land requires refined methods of control. The size of furrow stream should be neither excessive nor too small if a high application efficiency and a minimum amount of erosion is desired. To provide the refined control required to accomplish this, water control devices, such as siphons, spiles, and gated pipe have been developed, and their hydraulic characteristics tested and observed in the laboratory and in the field. In order to obtain a maximum operation efficiency from these devices, the head under which they operate must be carefully controlled. Rotary control gates, canvas by-pass check dams, and other devices can be used quite satisfactorily for this purpose.

This bulletin presents an evaluation of some water control devices tested in the laboratory and in the field. An evaluation is made of their effectiveness in controlling small streams of water, their susceptibility to clogging, and their characteristics in causing or preventing erosion as the water discharges from the devices.

The research project under which this work was conducted was concerned primarily with the control of water on steep irrigated lands. For that reason, the tests and equipment were limited primarily to low heads and relatively small streams of water.

As additional hydraulic and evaluation data on water control devices are made available, technicians will have a basis for further encouragement in the use of such equipment by farmers.

Experimental Work

Tests were conducted in the irrigation laboratory to determine the hydraulic characteristics of various water control devices. Siphons, spiles, furrow tubes, and gated pipe, all used in surface irrigations, were tested. The operational characteristics of these and other water control devices were also observed under field conditions at the Caldwell Branch Experiment Station.

* Formerly Graduate Fellow, Agricultural Engineering Department, and Associate Professor and Irrigationist, Agricultural Engineering Department, now U.S.D.A. Agricultural Research Service, Reno, Nevada.

Laboratory Testing Procedure

SIPHONS

Tests were run in the laboratory to determine the discharge, at various heads, of aluminum and plastic siphon tubes with internal diameters ranging from 0.5 to 2.0 inches. Both anti-wash bend and plain siphon tubes were tested.

Figure 1 shows the apparatus used to obtain the discharge of siphon tubes at various heads. The function of the various parts indicated are as follows: The hook gage B was used to measure the vertical distances from the datum plane A to the water surface in the stilling well C and to the center of the discharge end of the siphon tube E. The adjustable siphon holder D was constructed to raise or lower the discharge end of the tube for varying the head.

Head differentials from 0.15 to 2.0 feet were obtained by controlling the water levels in the flume and by raising or lowering the discharge end of the siphon tube. Discharge was determined by measuring the time required to fill a container of known capacity. Five tests were run at each head differential to secure an average value of discharge for the siphon at each head. The water level in the flume was measured before and after each test to make certain there was no fluctuation in the head.

Curves relating head in feet to discharge in gallons per minute were plotted.

The ideal discharge may be expressed by the equation

$$Q_i = A \sqrt{2gH} \qquad (1)$$

where

Q_i = The ideal discharge in cubic feet per second

A = The internal cross-sectional area of the tube in square feet.

g = The acceleration due to gravity = 32.2 ft/sec/sec.

H = The head in feet causing flow through the tube

The actual discharge (Q) does not equal the ideal discharge because of entrance, exit, and tube losses and may be expressed

$$Q = CA\sqrt{2gH} \qquad (2)$$

or

$$C = \frac{Q}{A\sqrt{2gH}} \qquad (3)$$

The coefficient of discharge (C) may be calculated using equation (3).

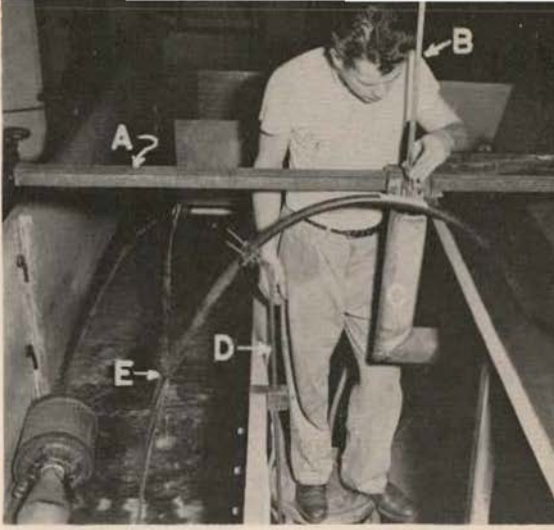

Figure 1. — Laboratory apparatus for measuring siphon tube discharge at various heads.

GATED FURROW TUBES

The flume used in testing the siphons was modified in order to run discharge tests on the gated furrow tubes. The tubes were soldered into the side of the flume, with their inlet ends projecting approximately 3/4 inch inside the flume. The gates were on the outlet ends of the tubes.

The head differential was determined with a hook gage by measuring the vertical distance between the water surface in the stilling well and the center of the discharge opening of the furrow tube. Each gate opening was calibrated separately. The shape of the opening, other than when fully open as shown in Figure 2, was traced on paper and the cross-sectional area measured with a planimeter. All cross-sectional areas were reduced to equivalent circular areas and diameters.

The procedure followed in determining the actual discharge of gated furrow tubes was the same as that used with siphon tubes.

The equations used for siphons were also used to complete the theoretical discharge and coefficient of discharge.

Figure 2. — Sketch of a calibrated control gate set at No. 2 opening.

GATED SPILES

Gated spiles are similar in construction and operation to gated furrow tubes. However, the length of the tube and shape of the gate makes the hydraulic characteristics somewhat different.

A small metal flume was constructed to test the discharge characteristics of the gated spiles. Holes were cut in the side of the flume and the gated spiles placed in position with their inlet end projecting 1 inch inside the wall of the flume. They were then secured with solder, forming a watertight bond between the flume and the tube. Figure 3 shows the flume with the hook gage in position to measure the ver-

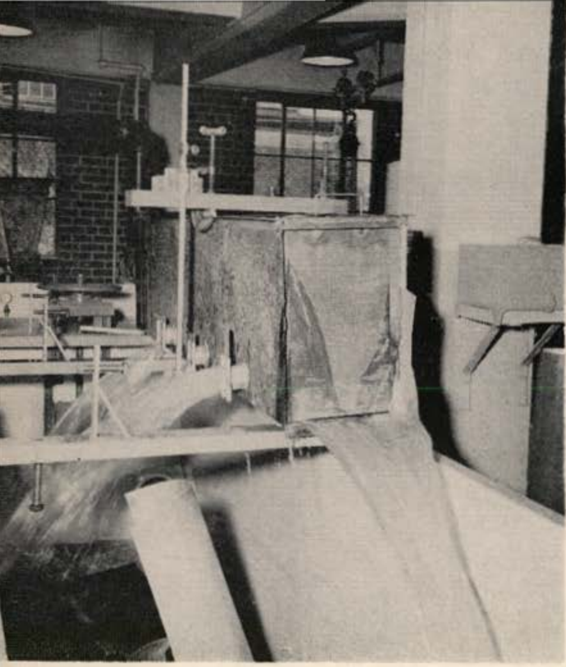

Figure 3. — Flume with hook gage in position to measure the vertical distance to the center of discharge opening of the spiles.

tical distance to the center of the discharge opening of the spiles. A stilling well was used to get an accurate measurement of the water level in the flume. The gates of the spiles were calibrated, and the cross-sectional area at the various openings found in the same manner as for the furrow tubes.

The testing procedure followed in measuring the actual discharge of the spiles at the various gate openings was the same as that used in testing the siphons.

GATED PIPE

Gated pipe 4 inches in diameter with gates spaced every 36 inches was also tested to determine hydraulic losses.

Figure 4 shows the pressure tank A, to which the inlet end of the gated pipe was connected. This tank contained a set of baffles which reduced the turbulence of the water to a minimum before it entered the gated pipe. The inlet pressure head was measured with a piezometer tube "B" connected to the pressure tank. Water, by-passed at the outlet end of the pipe, was diverted into a calibrated sump. A second piezometer measured the head at the last open gate.

The pipe was set at a slope of 1 in 300 as recommended by Hansen (9). Equal flow from each gate was obtained by adjusting the outlet valve at the end of the lengths of pipe. Test runs were made at various head differentials.

The water entering the pipe was measured by a meter, the water flowing from gates was held in the flume, and the water flowing past the last open gate was measured in the calibrated sump for a known period of time. From these data, the average discharge per gate was calculated using the following formula:

$$\text{GPM per gate} = \frac{[\text{Meter (cu ft)} - \text{Sump (cu ft)}]\ 448.8}{(\text{Time in seconds})\ (\text{Number of gates})}$$

where 448.8 is the factor used to convert cubic feet per second to gallons per minute. The difference between the heads at the inlet,

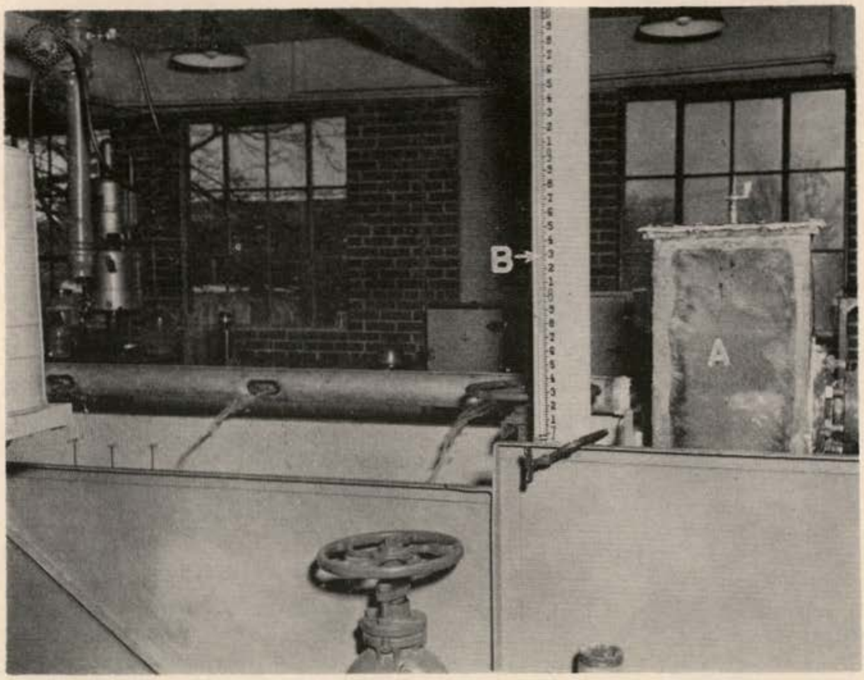

Figure 4. — Pressure tank and manometer tube used in testing gated pipe.

H_1, and the last gate, H_2, was divided by the number of gates to obtain the average head loss in the gated pipe per gate, that is,

$$\text{Average head loss per Gate} = \frac{H_1 - H_2}{\text{Number of Gates}}.$$

These values were then used to plot the discharge curves for gated pipe.

Field Testing Procedure

The effectiveness of the various water control devices was observed under field conditions during an irrigation season. Siphon tubes, gated furrow tubes, gated spiles, gated pipe, canvas distribution hose, rotary water control gates, by-pass canvas check dams, and a float valve were installed and used on the Caldwell Branch Experiment Station.

Experimental plots of beans were laid out for the study of the measurement of erosion occurring under furrow irrigation on steep land (4 to 5 percent slope), and the various control devices were employed to control the water in the head ditches and distribute the water to the furrows. Figure 5 is a sketch showing the irrigation ditches and the locations of the devices used in controlling the water level.

Water was diverted from the ditch into the gated pipe and canvas hose by means of 6-inch diameter concrete head gates and cylindrical metal tubes. The siphon tubes were merely primed by hand and laid over the ditch bank with their discharge end lower than the water level in the ditch. The rate of flow from the tubes was regulated by raising or lowering the discharge ends. The furrow tubes were buried in the bank of the ditch, with their control gate on the downstream side. The gated spiles were used in conjunction with the canvas hose, by inserting them into the ends of the distribution sleeves and using wire to clamp the hose to the tubes.

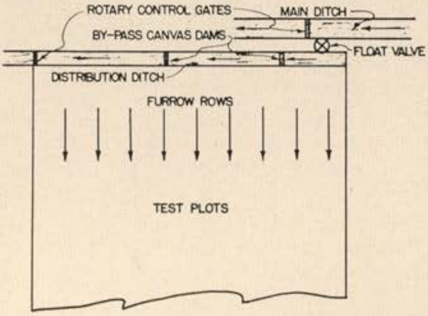

Figure 5. — Sketch showing the locations of the devices used to control the water level in the main and distribution ditch.

The effectiveness of the water control devices was observed through a varying range of conditions. During the irrigation season water from the canal contained varying amounts of trash, such as weeds and moss, and at times the devices were operating under the most adverse field conditions. When water from the Experiment Station well was used, the flow conditions approached those encountered in the labatory.

A trash screen was installed late in the season in one of the irrigation ditches on the Experimental Station in order to observe its effectiveness in removing trash from the water and its susceptibility to clogging.

Results of Laboratory Tests

The methods used in obtaining these results are given in the section of this report entitled "Laboratory Testing Procedure." The data obtained in the laboratory were used to obtain the actual discharge and the coefficient of discharge. The slope of the curves shown in the Appendix are equal to the discharge coefficient.

SIPHONS

The values presented in the Appendix for siphons, spiles, and furrow tubes, were obtained by actual measurement or were computed.

The values of discharge in gallons per minute versus head in feet were plotted on logarithmic graph paper (Figures 11 to 20). The curves drawn through these points are shown as a solid line, the slope of which is equal to the coefficient of discharge. Other curves were obtained by logarithmic interpolation and extrapolation and are indicated with broken lines.

The final results of the discharge tests run on plain plastic siphon tubes are summarized in Figure 6. These curves represent the average values of discharge versus head in feet for all of the plain plastic siphon tubes, from ½ to 1½ inches in diameter, except those that were deformed.

Average curves were not drawn for the plastic and aluminum antiwash bend or plain aluminum siphon, as discharge tests were not run on a sufficient number of the various sizes to make it justifiable.

GATED SPILES AND FURROW TUBES

The curves obtained in running discharge tests on the gated spiles and furrow tubes appear in the Appendix, Figures 21 to 30. The values shown were computed in the same manner as those for the siphon tubes. Each group of curves indicates the discharge of one gated spile or furrow tube at the various calibrated openings.

The smaller tubes ran full even at low head differentials with the control gates entirely open. However, the larger diameter tubes did not flow full at the lower heads when the gates were fully open. It can be seen that there is a considerable range in the variation of discharge at the several gate openings. Therefore, these devices offer an excellent means of controlling the flow of irrigation water under a wide variety of conditions.

GATED PIPE

The results obtained in the tests run in the laboratory on gated pipe are shown in Figures 31 to 33, Appendix. Each curve indicates the average discharge to be expected from one gate and the head loss to be expected per gate at a certain width of opening.

At heads higher than those depicted by the curves, it was not possible to obtain an even flow from the gates throughout the entire length of the pipe. It is doubtful whether a higher head would be desirable as the jets of water flow from the gates at a velocity that would cause excessive erosion. The gated pipe offers a refined method of controlling fine streams of irrigation water.

Results of Field Tests

The water control devices tested in the laboratory, and others, were used under actual field conditions, and observations made of their operational characteristics throughout an irrigation season.

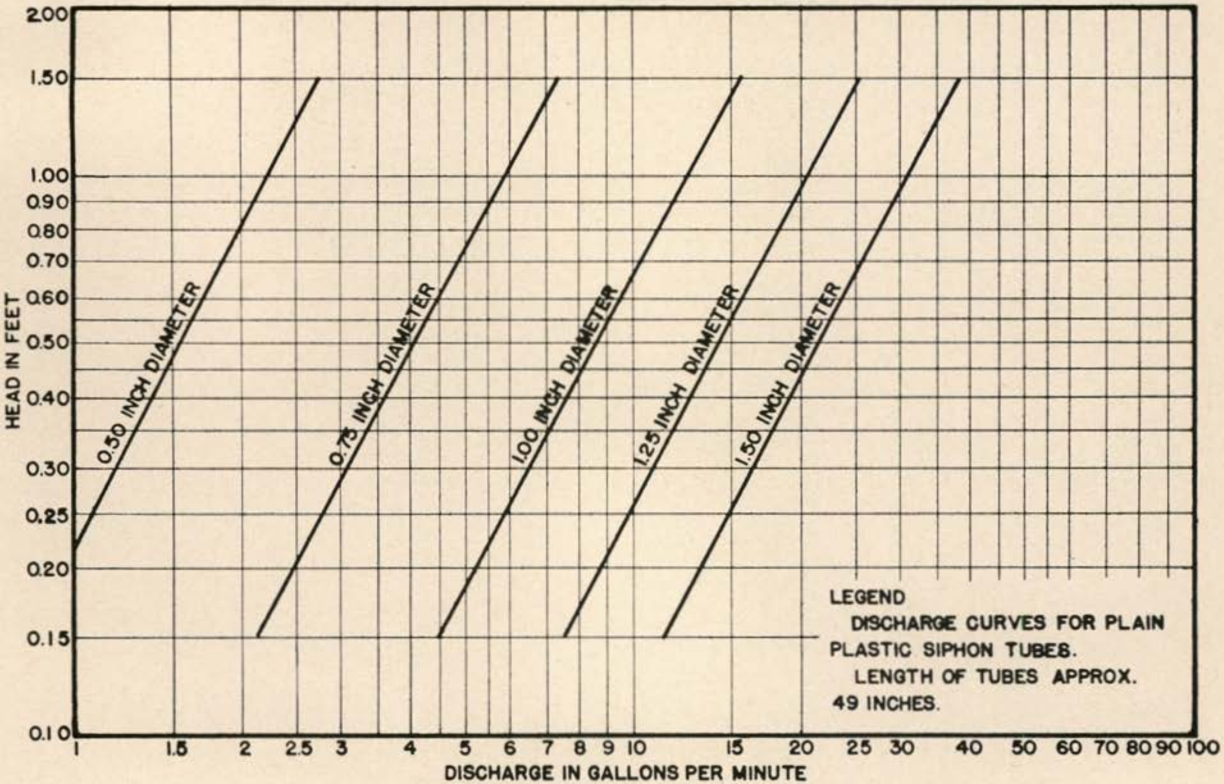

Figure 6. — Discharge curves for plain plastic siphon tubes.

SIPHONS

Siphon tubes, from ½ to 1½ inches in diameter were used in distributing water to the bean field furrows, which had a slope from 4 to 5 percent. The effects of trash on the functional characteristics of the siphons was observed during the season. Trash that floated on the surface of the water did not affect the flow characteristics of any of the siphons to any great extent, as their inlet ends were below the water surface. However, suspended material, such as moss, had a tendency to completely or partially plug the tubes. The plugging of the tubes having diameters of less than ¾ inches was especially noticeable.

The hydraulic action of the water flowing from the discharge ends of anti-wash bend tubes caused less erosion than that flowing from plain siphons. This is explained by the angle at which the water strikes the soil. The water flowing from the plain tube strikes the soil at an angle of approximately 45 degrees, while this angle is almost zero degrees when the anti-wash bend tubes are properly set. The anti-wash bend tubes were slightly harder to prime than the plain ones.

Some siphons were equipped with slip-on control gates which control the discharge and dissipate the energy of the stream before it strikes the soil. The dissipation of energy is accomplished when the stream strikes the gate.

An attempt was made to use the long rubber siphon hoses, but they were undesirable because they were unwieldy and almost impossible for one man to prime.

The polyethylene siphon tubes proved to be flexible and not easily damaged by rough handling. The other plastic tubes, such as tenite, were more brittle and it was not possible to remove dents when they were deformed. Clear polyethylene plastic will deteriorate in time due to infra-red rays, while the tenite type of plastic reflects the rays and is not affected. Aluminum tubes, deformed by rough handling, could not be reformed to their original shapes nor indentations removed without considerable difficulty.

Figure 7. — Device used in setting siphon tubes at a desired head.

The device shown in Figure 7 provides an easy and practical means of measuring the head under which a siphon tube operates in the field.

To measure the head differential under which a siphon tube is operating, the leg is adjusted so that point A is set level with the water surface in the ditch. Then the level is used to bring the device into a horizontal position so that A and A′ are on the same datum plane. When the device is level, with point A even with the water surface, the head differential can be read directly on the scale at A. The movable scale can be set at any desired head, which makes it easy to place siphon tubes in position to deliver a desired discharge.

GATED FURRROW TUBES

The furrow tubes were buried in the ditch bank and left throughout the irrigation season. They proved to be a satisfactory means of delivering water to the furrows. Weeds or moss did not cause plugging except when the gate openings were very small. Clean irrigation water would increase the effectiveness of the furrow tubes.

GATED SPILES

The gated spiles were used in conjunction with the canvas hose (Figure 8). That is, the tubes were inserted in the ends of the distribution sleeves and the gates were used to control the size of furrow streams.

Figure 8. — Gated spile used in conjunction with canvas distribution hose.

This proved to be a satisfactory and versatile means of controlling the discharge. Trash and moss, however, decreased the rate of flow when they lodged in the gate openings. Because of the wide range of discharge rates made possible by the control gates, gated spiles can be used under varying conditions of slope and soil type.

GATED PIPE

Ames slip-joint (Q C L) quick-coupler, and Pohl gated pipe were used in irrigating the experimental plots. The Ames quick-coupler pipe is equipped with steel slide gates which are hard to adjust. The QCL coupler makes a good connection and forms a water-tight seal. The Ames slip-joint pipe, made of galvanized metal, is equipped with neoprene slide gates. These gates are very easy to adjust. The neoprene gates can be fitted with soil socks which tend to greatly reduce the amount of erosion caused by the stream of water issuing from the gate. The metal slip-joints are difficult to join or take apart and it is not easy to stop leakage around the joints. The Pohl aluminum gated pipe is equipped with diaphragm type control gates, which are adjusted by turning the headed tube of the discharge opening. The joints are sealed against leakage by the water pressure in the pipe.

The weight of the pipe made a difference in the amount of labor required when changing locations, therefore, the aluminum pipe was more desirable and easier to handle than the galvanized pipe.

All types of trash caused the gated pipe openings to clog to some extent. Weeds would lodge across the openings of the gates and cause the discharge to fluctuate. However, when moss was carried by the irrigation water, the greatest amount of clogging was observed. When trash-free well water was used the gated pipe controlled the discharge into the furrow rows effectively. This indicates that in order to control the size of furrow streams effectively, using gated pipe, weeds and moss should be removed from the irrigation water. There must also be a positive control of the head under which the device is operating.

CANVAS DISTRIBUTION HOSE

Canvas distribution hose, 5 and 11½ inches in diameter, was used to control the furrow streams applied to a portion of these test plots. The distribution sleeves were either tied off with twine, or gated spiles were inserted in the ends of the sleeves to adjust the discharge. The use of twine to control the discharge was effective, but, a closer adjustment was possible when the gated spiles were used in conjunction with the hose.

The hose is made of treated canvas, the seams of which are water-tight. The canvas hose seems to be very durable and, according to the manufacturer, will have a life expectancy of from four to five years or more if properly cared for. The 50-foot sections of hose proved to be quite portable. The hose was especially applicable when used in replacing head ditches running down steep slopes.

The presence of weeds and moss in the irrigation water affected the efficiency of operation. Therefore, as with other devices used to control the rate of flow, a source of irrigation water free of trash would be desirable in order to obtain the most even distribution of water.

ROTARY GATES

A rotary gate (Figure 9) was used to control the water level in the head ditch, and another was installed in the supply ditch. The installation and removal of the gate was facilitated by attaching it to sheet metal cut especially for this purpose. The gate was moved to different locations during the irrigation season. The portability of the structure proved to be a desirable feature. The rotary gates were very easy to adjust and there was very little, if any, leakage around the gate.

Figure 9. — Rotary control gate used to control the water level in the head ditch.

CANVAS BY-PASS CHECK DAMS

The canvas dams with the by-pass sleeves, proved to be an excellent means of controlling the water level in the distribution ditch. The amount of water allowed to by-pass the dam was regulated by a wire draw-string in the end of the hose. The sleeve makes the dam heavier to move and rather hard to install. However, being able to by-pass part of the stream through the dam overcomes the disadvantage encountered in setting it.

TRASH SCREEN

A trash screen as shown in Figure 10 was installed in an irrigation ditch to remove trash from the irrigation water. It did this quite effectively and also removed silt and weed seeds. No evaluation concerning its susceptibility to clogging can be made, however, until it has been in use for at least another irrigation season.

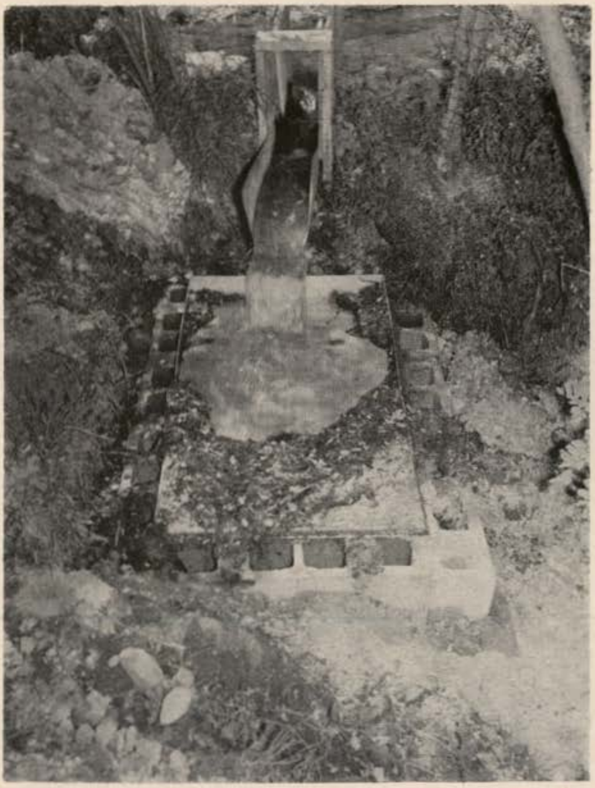

Figure 10. — Screen used in removing trash from irrigation water.

Comparison and Effectiveness of Water Control Devices in Controlling Discharge

The distribution of water into furrows on steep lands requires refined methods of control. For this purpose the hydraulic characteristics of a number of devices were tested and observed in the laboratory and in the field.

The laboratory tests were run under carefully controlled conditions where it was possible to maintain a constant water level in the flumes and, hence, a constant discharge from the devices at various head differentials. Discharge curves for siphons, gated spiles, gated furrow tubes, and gated pipe are shown in the Appendix. For plain plastic siphon tubes, a set of discharge curves was compiled from the results obtained in testing a number of different sizes of siphons. Discharge tests were not run on a sufficient number of the other types of siphon tubes to justify making composite curves for them. The use of larger diameter tubes than those indicated in Figure 6 would be unlikely on steep land because of their large discharge capacities.

In the field, adverse conditions were encountered which made it difficult to maintain constant rates of flow. The major causes of this were the fluctuations of the water level and trash, such as weeds and moss, contained in the water.

The siphon tubes were effective in controlling the discharge required to irrigate the steep land, of 4 to 5 percent slope, on which the test plots were located. The larger siphons were used to distribute water into several furrows, while the smaller ones served individual furrows. Weeds floating on the surface did not affect the discharge of the siphons as their inlet ends were below the surface of the water. Moss which was suspended in the water tended to lodge in the tubes and wholly or partially stop the flow of water. The smaller tubes were especially prone to plugging. Using the device shown in Figure 7, and the discharge curves from the Appendix and Figure 6, it was possible to set the siphons to deliver a desired discharge. This is especially applicable when it is desired to direct the maximum non-erosive stream into a furrow at the beginning of an irrigation and later cut the furrow stream to a minimum.

The gated furrow tubes effectively controlled the discharge into the furrows. Their wide range of discharge makes them useful under many and varied conditions encountered in irrigation. By using the device made for setting siphon tubes and the discharge curves for the various calibrated openings it was a simple matter to obtain the rate of flow desired.

The canvas distribution hose (Figure 8) proved to be a versatile means of apportioning water to the furrows. Adjusting the rates of flow by tying the sleeves with twine served very well; however, the use of the calibrated gated spiles in conjunction with the canvas hose gave a more precise control of the discharge. Trash lowered the operational efficiency when it became lodged in discharge openings of the tied sleeves or the gated spiles.

For the distribution of water into the furrows of the test plots, on which erosion studies were conducted, gated pipe proved to be the best means of controlling the size of furrow stream. By setting the pipe at a slope of 1 in 300, as recommended by Hansen (9), and adjusting the gates to deliver a desired discharge the rate of flow remained constant as long as the head did not fluctuate or the openings did not become plugged by trash. A stop watch and a container of known volume were used to measure the desired discharge.

To control the water level in the head ditch, a float valve, canvas by-pass check dams, and rotary control gates were utilized. The amount of water diverted from the supply ditch into the head ditch was efficiently controlled by the float valve. The canvas by-pass check dams and the rotary control gates controlled the water level in the head ditch quite effectively. Both the canvas dams and the control gates were easily moved from one location to another.

Comparison of Erosion Caused by Water Control Devices

Streams of water issuing from the outlets of some of the water control devices tested in the field caused considerable erosion when nothing was done to dissipate the energy of the stream before it struck the soil surface. Some of the commercially manufactured devices were equipped with attachments designed especially for this purpose.

Streams of water flowing from the anti-wash bend siphon tubes caused less erosion than those discharged from plain siphons. This is explained by the angle at which the water comes in contact with the soil. Some of the plastic siphons were equipped with slip-on control gates which not only regulated their discharge but tended to dissipate the energy of the water before it struck the soil.

The gated furrow tubes did not cause an excessive amount of erosion when operating under low heads; however, as the head increased, the erosion caused by the stream emitting from the outlet also tended to increase.

The gated spiles used in conjunction with the canvas distribution hose did not appear to cause an excessive amount of erosion. Water discharged from canvas sleeves tied with twine cause even less erosion.

The erosion caused by water flowing from the outlets of gated pipe was of considerable magnitude when no attempt was made to reduce the erosive force.

A very practical method of reducing erosion caused by streams of water emitting from devices is to place a piece of old burlap or a used fertilizer bag at the point where the discharge strikes the soil.

Advantages and Disadvantages of Water Control Devices

Each device may have its special advantages or disadvantages; however, these presented here will apply generally to all the devices tested.

ADVANTAGES

1. After the irrigation system has been designed and installed in a field, the maintenance of siphons, spiles, gated pipe, or other devices will be at a minimum.
2. The devices used to deliver water to the furrows accomodate some fluctuation in head without excessive variation in discharge.
3. On steep land, the easy adjustment of discharge from the devices offers the distinct advantage of making it possible to have the furrow flow a minimum as it reaches the end of the furrow.
4. All of the devices are portable and easily moved from one location to another.
5. The life expectancy of most of the devices are such that they outweigh a rather high initial cost.

DISADVANTAGES

1. In some instances, the high initial cost makes the use of the devices questionable.
2. The devices are susceptible to plugging by trash contained in most water used in surface irrigation.
3. When using siphon tubes, if for some reason the flow is interrupted, it is necessary for the irrigator to reset the tubes.

Summary

Discharge tests were conducted in the laboratory under carefully controlled conditions using equipment constructed especially for this purpose. The results of these tests are presented in this bulletin in the form of curves which show the amount of discharge to be expected from siphons, gated spiles, and gated pipe. These curves can be used to advantage in the design of surface irrigation systems.

The discharge coefficient of the various siphon tubes became larger as the inside diamter of the tubes decreased and as the length of the tubes increased. This change in the discharge coefficient can be noted by examining the slopes of the curves shown in the Appendix, Figures 11 to 20.

The larger gated spiles did not flow entirely full when set at their widest opening and when operating under low heads (Figure 25, Appendix), the discharge coefficient decreased at the smaller gate openings as indicated by the slope of the discharge curves, Figures 31 to 33, Appendix, represent the head loss of the discharge curves, Figures 31 to 33, Appendix, represent the head loss per gate for one type of gated pipe at various rates of discharge.

The operation of the devices tested in the laboratory, and others, were observed while being used for irrigation purposes. It was found that the water passing through the various devices must be free of trash and a constant head maintained to insure efficient operation.

The siphon setting device described previously can be used to advantage when a siphon tube is used for irrigation. This device provides an easy and practical means of measuring the head under which a siphon tube operates in the field.

The initial cost of an irrigation system may be high when these water control devices are used, but the efficiency of operation and savings of time and labor soon overcome this initial disadvantage.

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Appendix

DISCHARGE CURVES FOR SIPHONS, SPILES, AND GATED PIPE

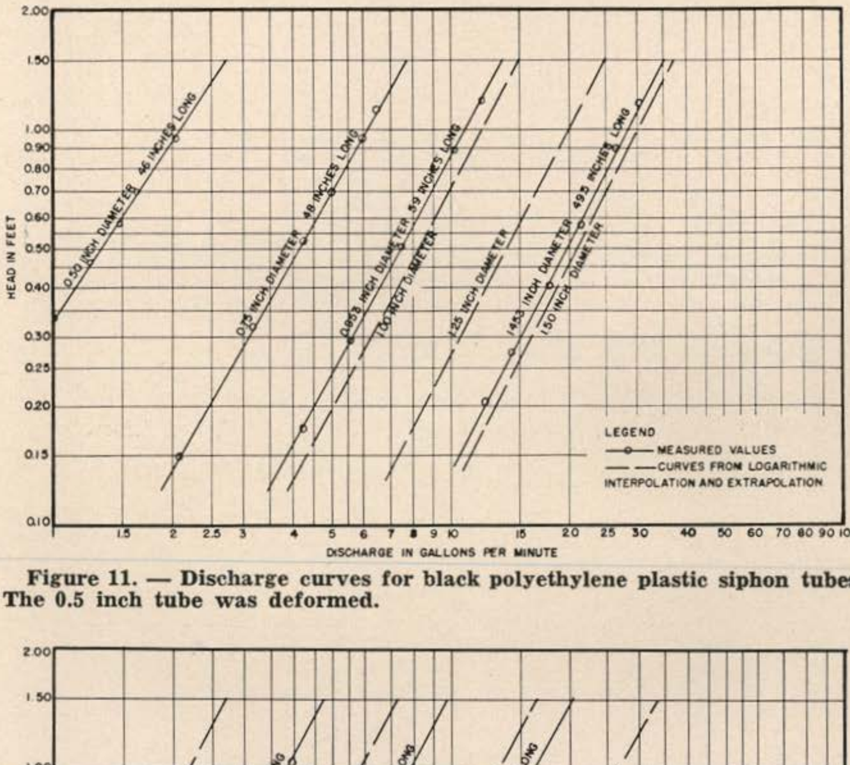

Figure 11. — Discharge curves for black polyethylene plastic siphon tubes. The 0.5 inch tube was deformed.

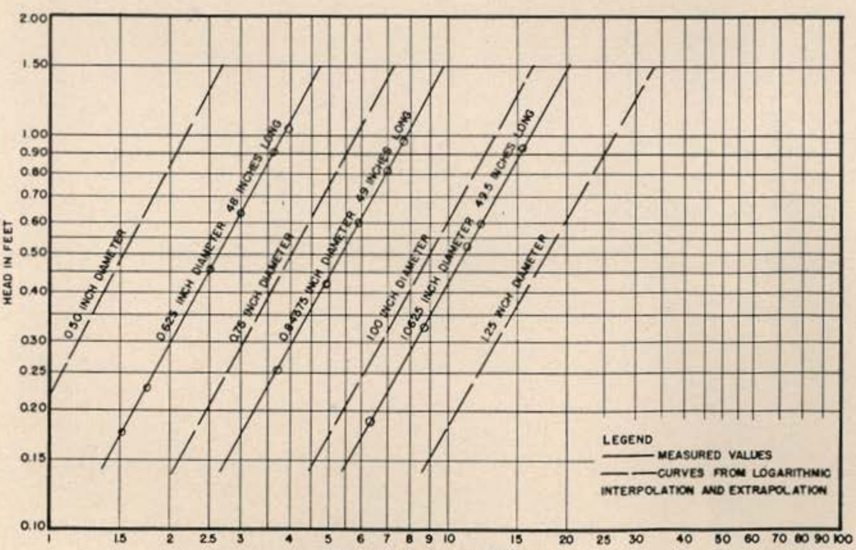

Figure 12. — Discharge curves for black polyethylene plastic siphon tubes.

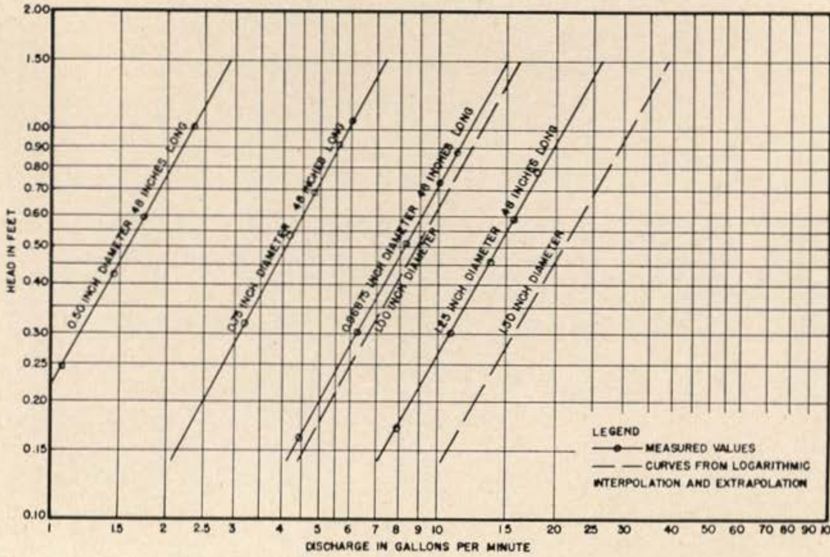

Figure 13. — Discharge curves for red tenite plastic siphon tubes.

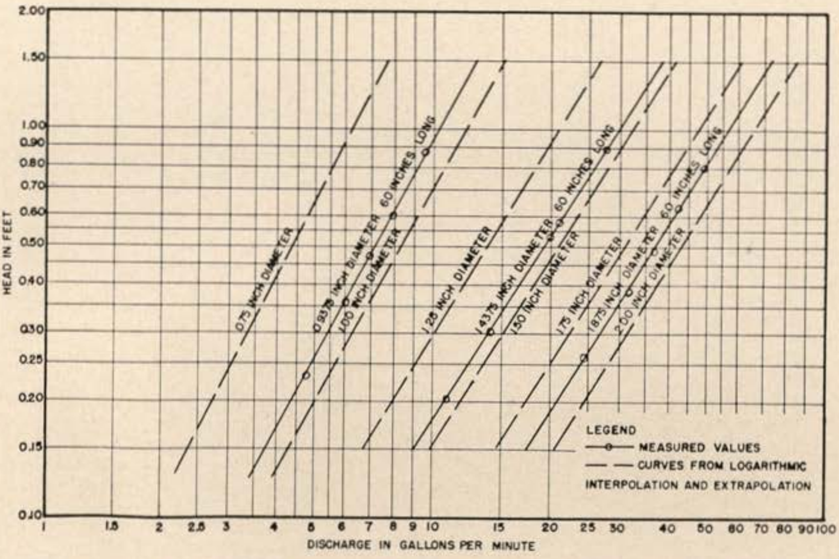

Figure 14. — Discharge curves for amber tenite plastic siphon tubes.

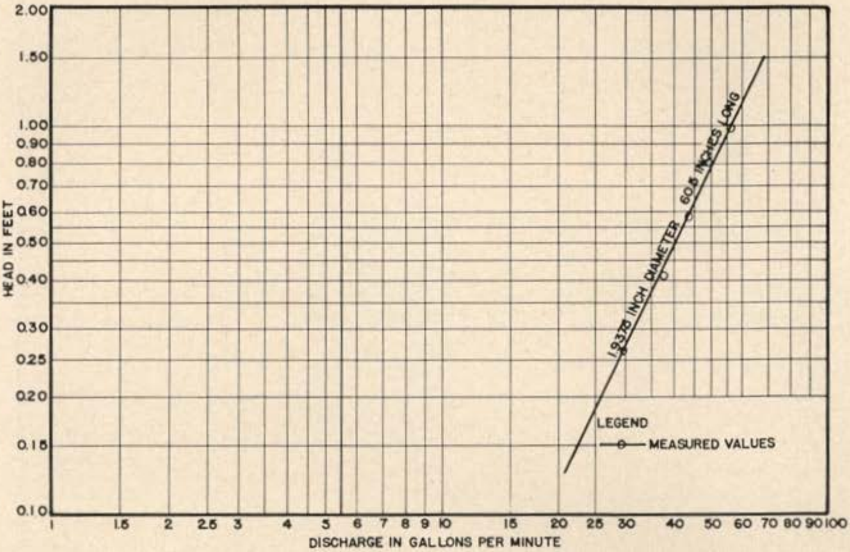

Figure 15. — Discharge curve for an aluminum siphon tube.

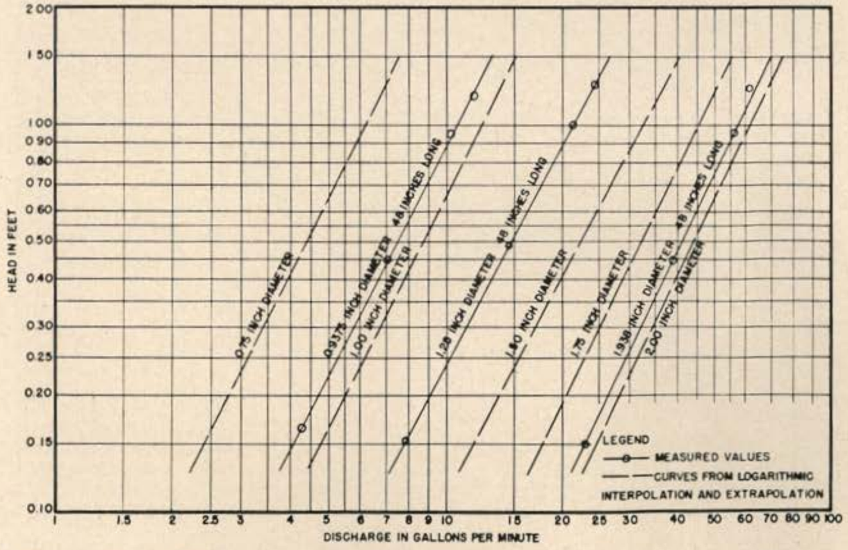

Figure 16. — Discharge curves for aluminum anti-wash siphon tubes.

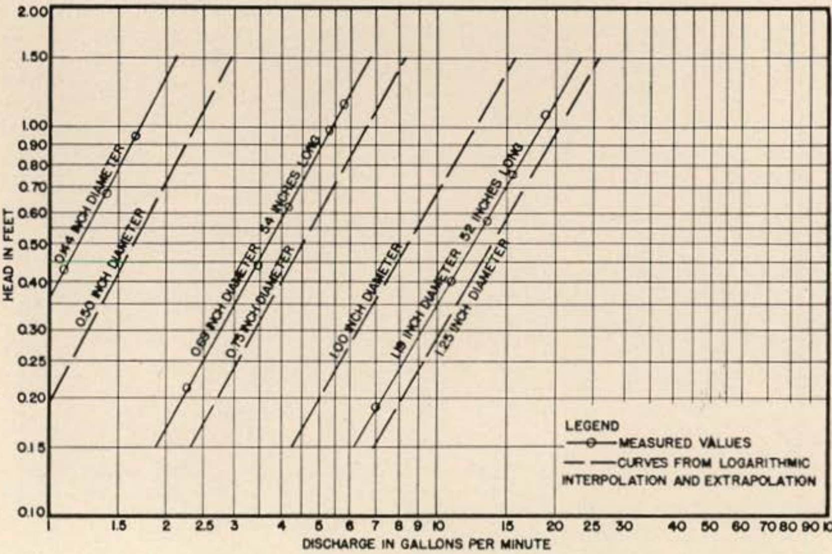

Figure 17. — Discharge curves for aluminum anti-wash siphon tubes.

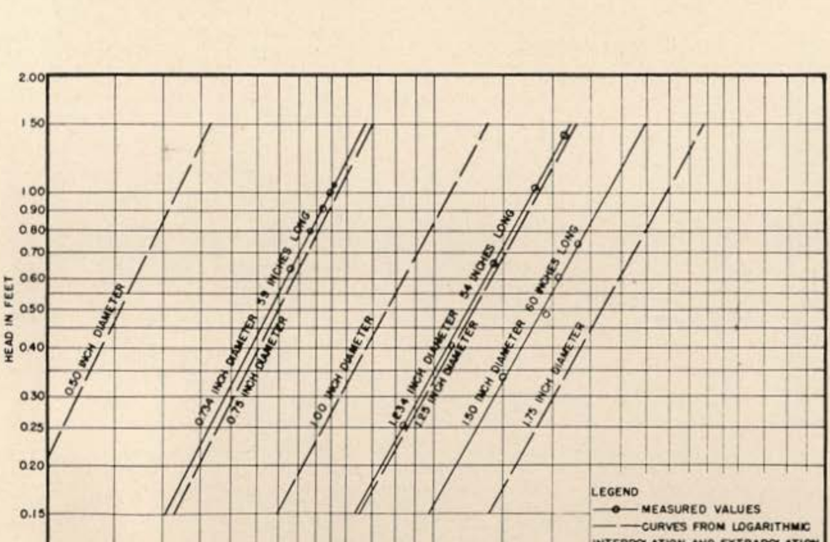

Figure 18. — Discharge curves for black polyethlene plastic anti-wash siphon tubes.

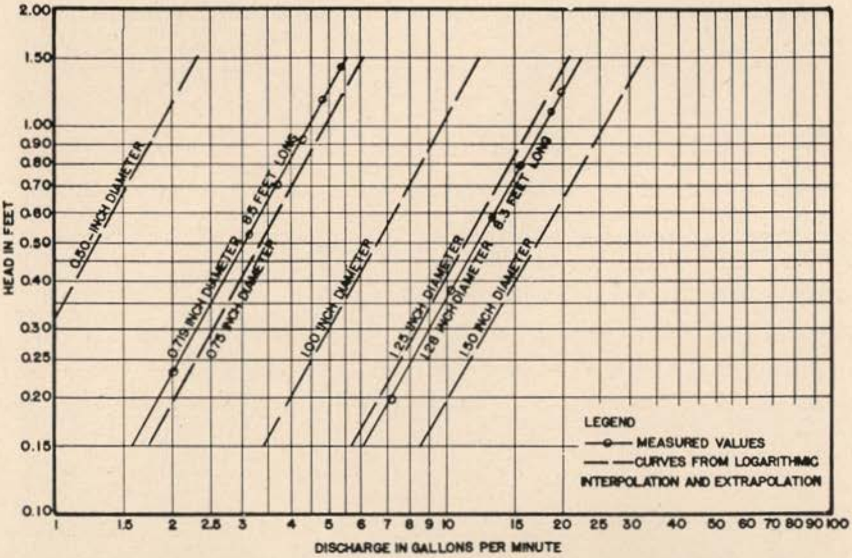

Figure 19. — Discharge curves for rubber wire-reinforced siphon hose.

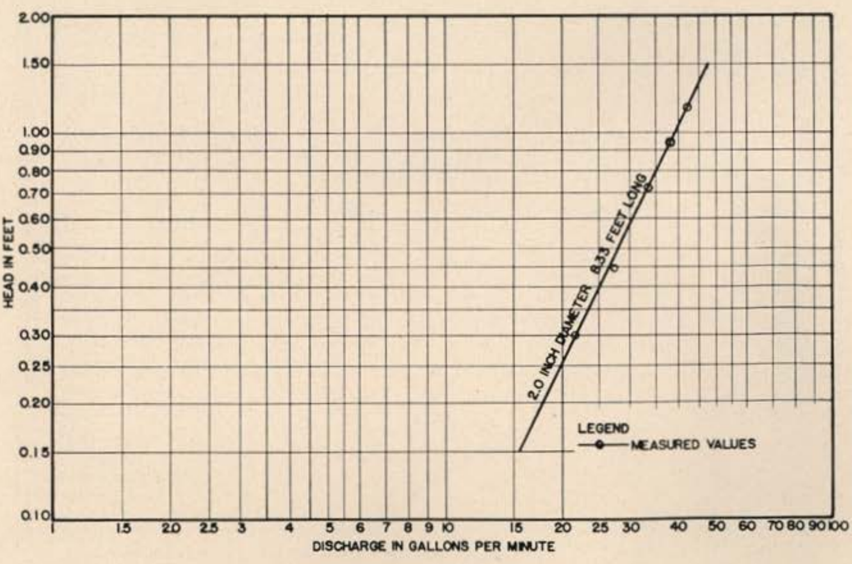

Figure 20. — Discharge curve for a thin-wall rubber wire-reinforced siphon hose.

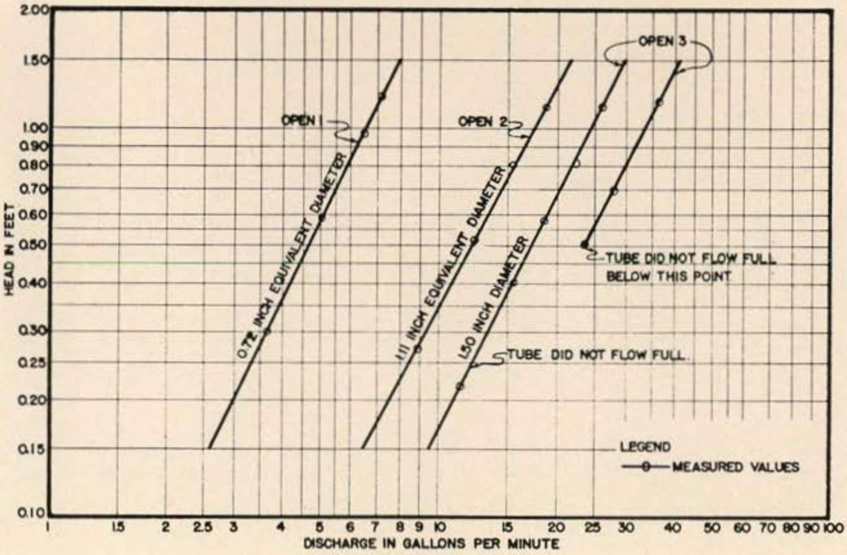

Figure 21. — Discharge curves for gated spile No. 2. Tube length 3 inches.

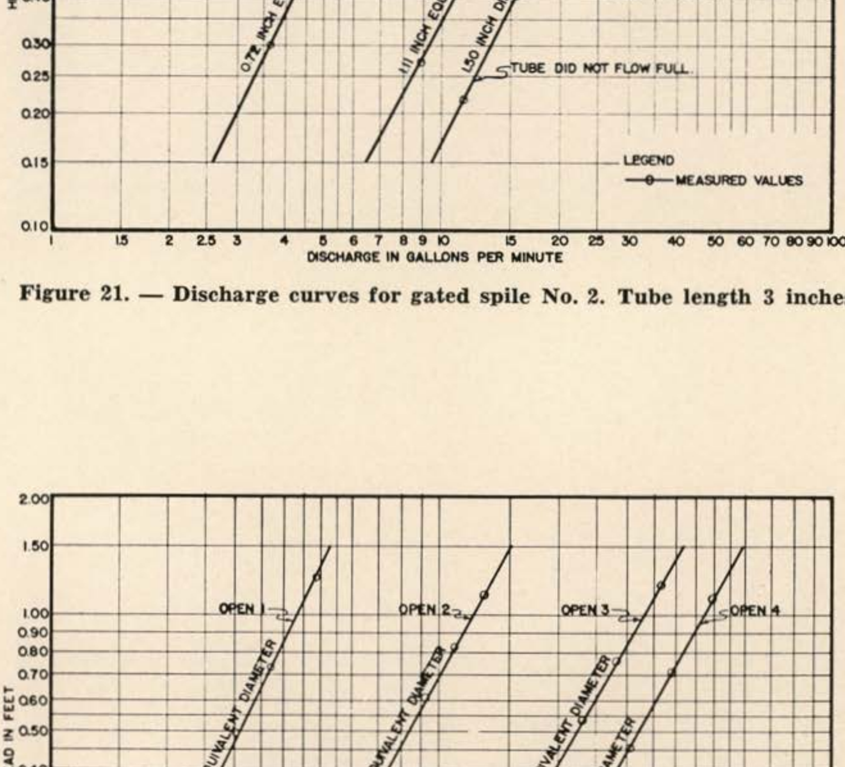

Figure 22. — Discharge curves for gated spile No. 3. Tube did not flow full at opening 4.

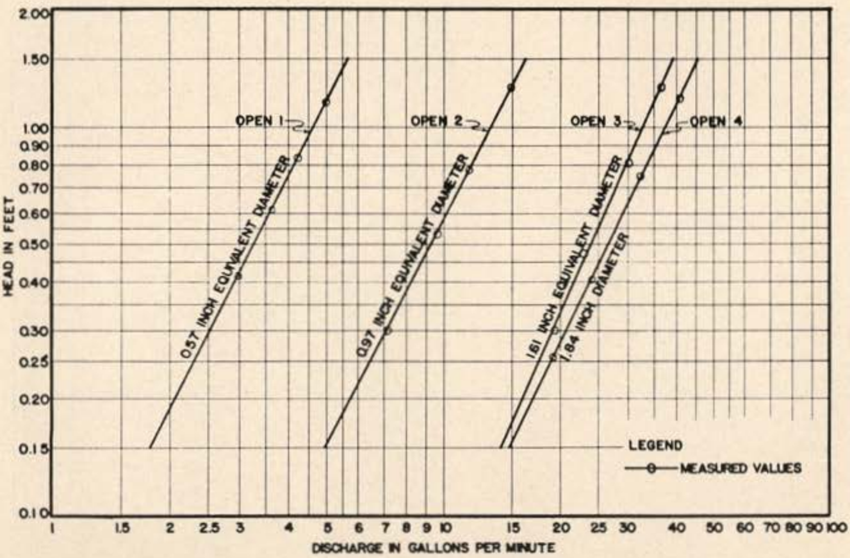

Figure 23. — Discharge curves for tapered tube gated spile (tube length 3¼ inches). Tube did not flow full at opening 4.

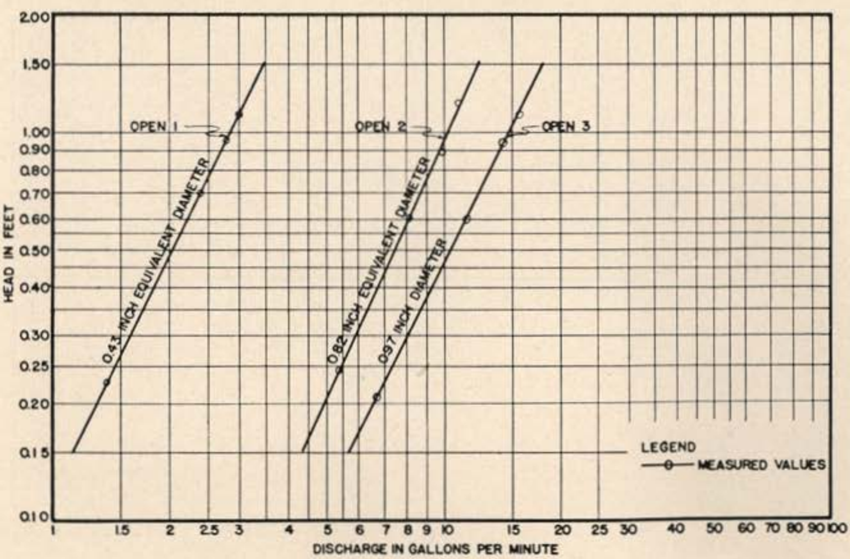

Figure 24. — Discharge curves for gated spile No. 1. Tube length 1½ inches.

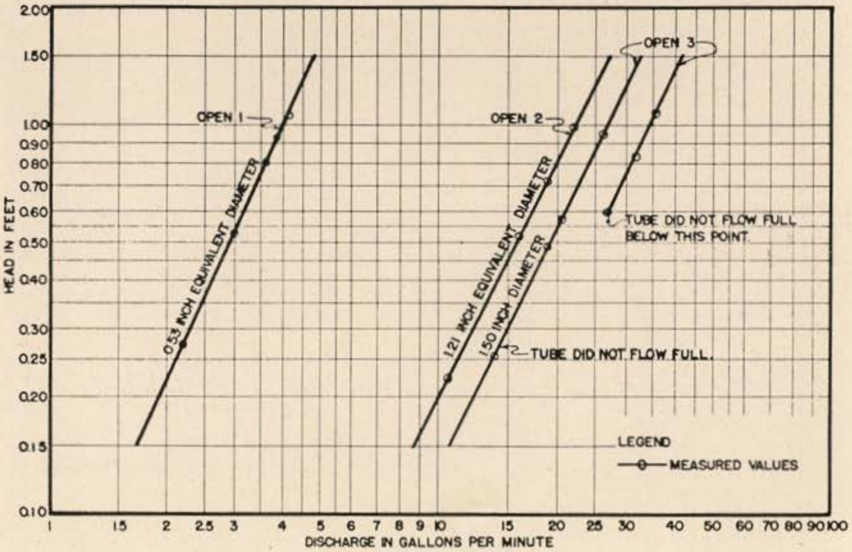

Figure 25. — Discharge curves for gated spile. Tube length 3 inches.

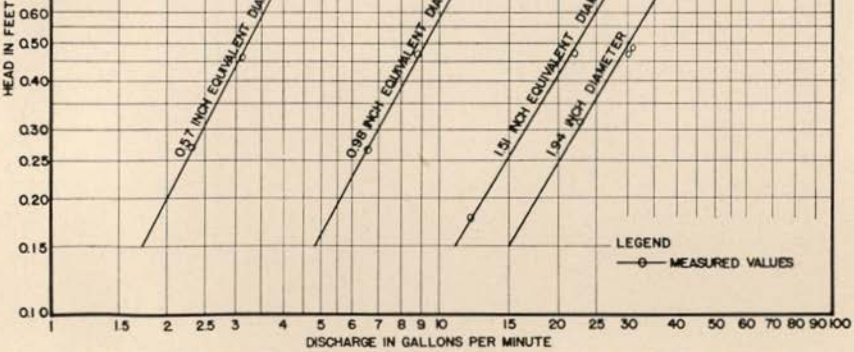

Figure 26. — Discharge curves for gated spile. Tube length 2 inches. Tube did not flow full at opening 4.

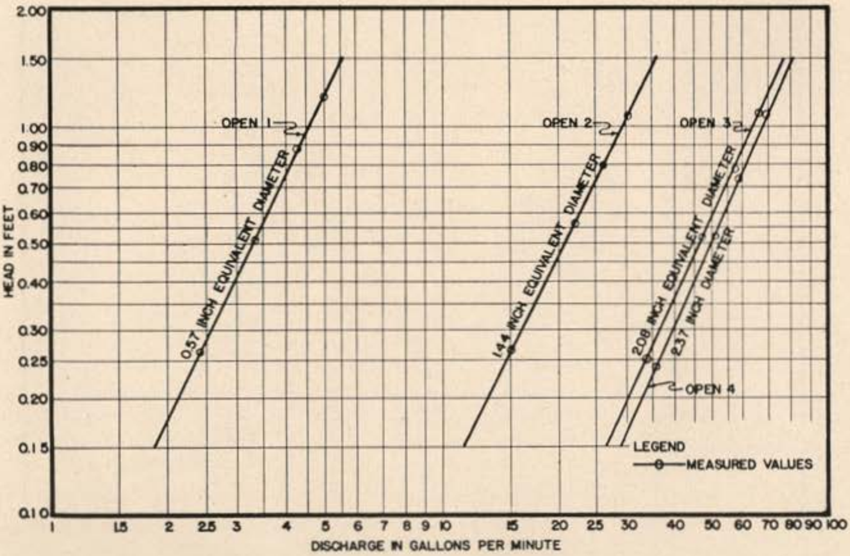

Figure 27.—Discharge curves for gated spile. Tube length 2½ inches. Tube did not flow full at opening 4.

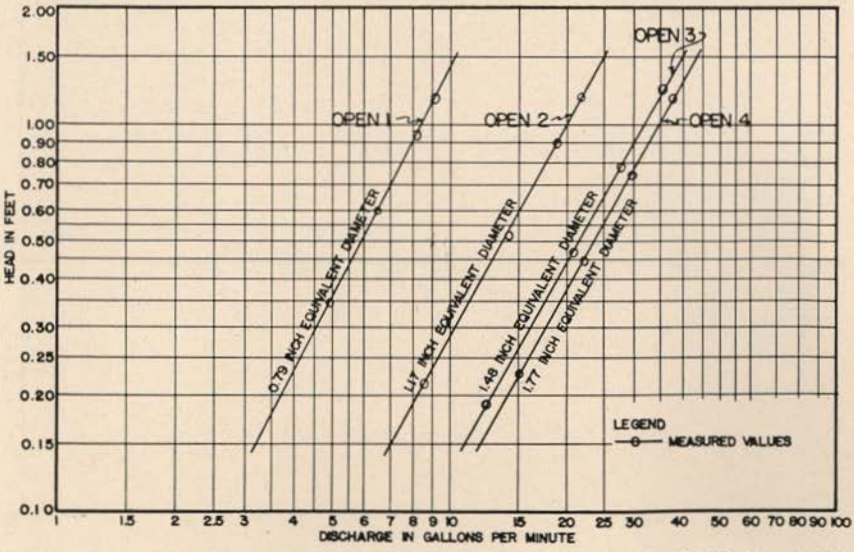

Figure 28. — Discharge curves for gated spile. Tube length 3¼ inches. Tube did not flow full at opening 4.

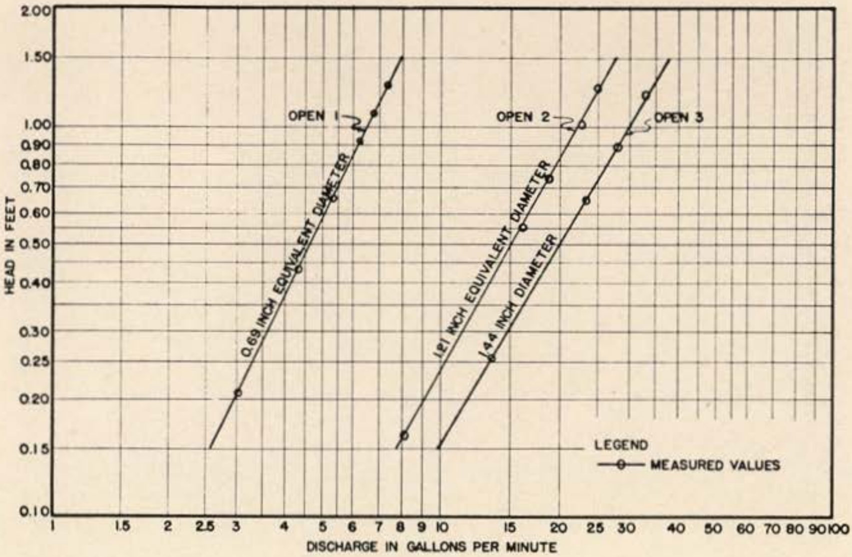

Figure 29. — Discharge curves for gated furrow tube No. 1. Tube length 30 inches. Gate on outlet end of tube.

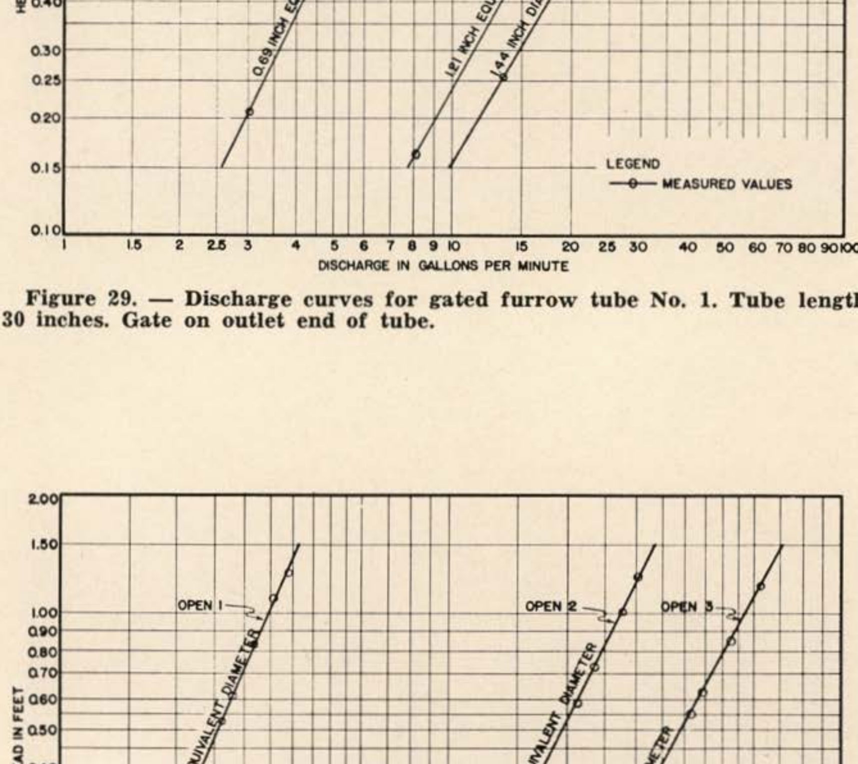

Figure 30. — Discharge curves for gated furrow tube No. 2. Tube length 30 inches. Gate on outlet end.

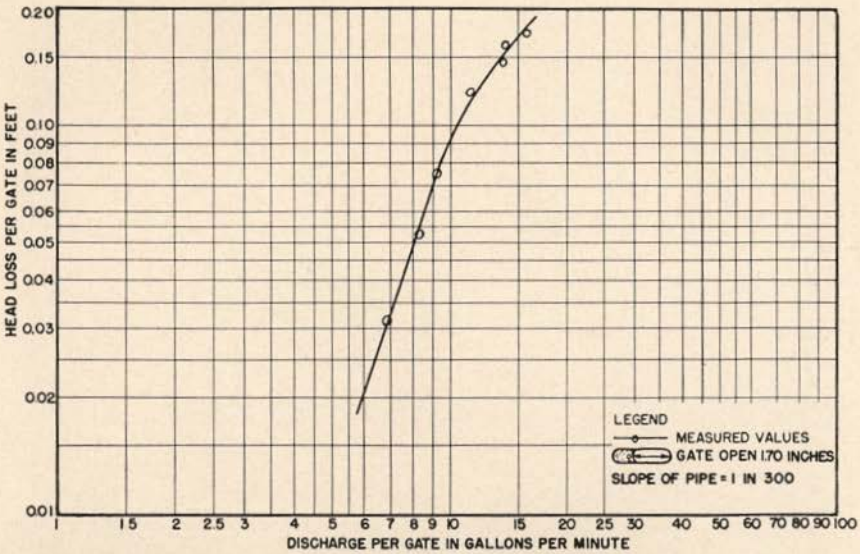

Figure 31. Discharge curve for slip-joint gated pipe, equipped with neoprene slidegates. Gate opening as indicated.

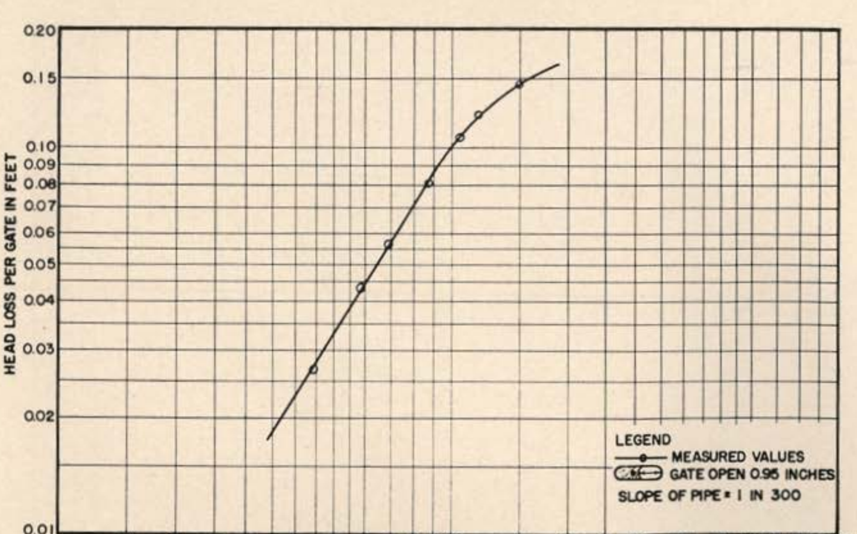

Figure 32. — Discharge curve for slip-joint gated pipe, equipped with neoprene slidegates. Gate opening as indicated.

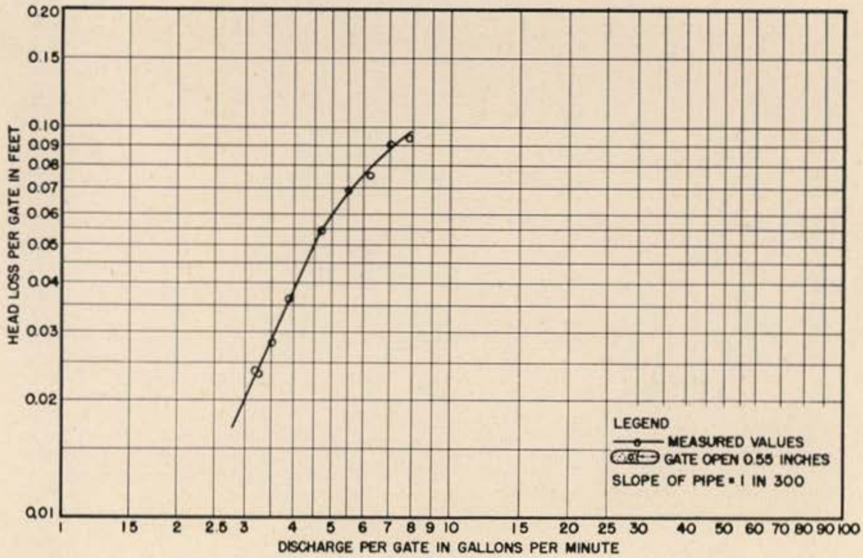

Figure 33. — Discharge curve for slip-joint gated pipe, equipped with neoprene slidegates. Gate opening as indicated.

5M—12-59