UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MEASURING SEEPAGE LOSS IN IRRIGATION CANALS

(TENTATIVE PROCEDURES FOR PONDING AND SEEPAGE METER TESTS)

Hydraulic Laboratory Report HYD-459

DIVISION OF ENGINEERING LABORATORIES

OFFICE OF ASSISTANT COMMISSIONER AND CHIEF ENGINEER
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FOREWORD

The principal objective of this report is to summarize tentative procedures for a guide in the performance of ponding and seepage meter tests in measuring seepage losses from canals. We encourage and request comments on these procedures for assistance in their improvement.

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INTRODUCTION

Seepage loss from canals is a problem of concern to irrigation engineers. The importance of knowing accurately the magnitude of such losses has increased with the need for utmost conservation of our water and land resources.

To conserve water and prevent land damage, a part or all of the canal or lateral may require some form of lining. Need for the lining can often be determined only through seepage loss measurements in the unlined canal. When a need is indicated, the lining may be of natural or manufactured materials and after placement their effectiveness in seepage reduction must be evaluated.

Seepage loss measurements may be made on the entire system, on long reaches of a conveyance or on points in a canal selected in a manner such that the results will be representative of larger areas. It is not the purpose of this report to discuss the many factors to be considered and the means of selecting the best method for use under particular field conditions, but rather to describe procedures for conducting tests using certain methods. The suggestions in the report have been compiled to assure a certain degree of uniformity in testing and results, so that comparisons of data from these tests may be made with little apprehension that differences in testing techniques are responsible for excessive experimental errors.

There are several known methods for determining seepage losses and others are in process of development. However, at present, there are three generally used methods for determining losses quantitatively; ponding, seepage meter, and inflow-outflow. Of these three, sufficient information is available to present a general procedure for conducting seepage loss tests by the ponding and seepage meter methods. There is insufficient information presently available to establish the best procedure for the inflow-outflow method.

Many factors affect the rate of seepage loss from a canal. Some of the more obvious ones are listed here:

1. Permeability of material traversed by canal
2. Depth of water
3. Wetted area
4. Location of water table relative to canal invert
5. Slope of subgrade soil structure
6. Flow velocity
7. Soil and water temperatures
8. Entrained air in soil
9. Ground-water inflow
10. Atmospheric pressure
11. Soil and water chemistry
12. Capillary attraction

The relative importance of each has not been definitely determined, though it is known that one may offset another, and some may even alternately produce an increase and a decrease in seepage rate.

With so many variables operating, it is considered impossible to write simple equations expressing the interrelationships which may exist. The theoretical approach to computing seepage losses must then be supplanted with empirical methods.

SECTION I--PONDING METHOD

General

The ponding method offers the most accurate means now known for establishing rates of loss. Various techniques of conducting ponding tests will be discussed in this section for the purpose of enabling field engineers to make tests on canals under their supervision.

Selection of the Test Site

Several factors may enter into the selection of a test site. The purpose for the test may automatically dictate the site. For example, if croplands adjacent to a certain length of canal have become waterlogged, or the water table has risen to a level which is causing crop damage, then the test reach should probably parallel the affected properties. If the purpose is to learn the effectiveness of a lining method or material, or to determine a loss rate for a particular soil type, more latitude may be allowed in placement of a pond. In cases where the canal is a proposed one, a representative section along or near the future centerline can be chosen, and the specific location will probably not be critical.

As a general rule, it is desirable to avoid selecting a reach along a curve in the canal. Sections in which there is a steep slope to the natural topography traversed should also be carefully considered before selection as a pond site. If possible, the pond should be free from reaches in which the subgrade materials vary considerably in composition. This is particularly true if the measured seepage rates are to be considered as representative of a certain soil type. A test section without turnouts is better than one with such devices since they are sources of leakage, and it may be difficult to evaluate the rates of loss through them.

Most canals have a service road which parallels the canal, and it will usually accommodate passenger cars and pickup trucks. If the canal is small, required materials for construction of the pond can be hauled by these vehicles. When the canal is large, motorized equipment, such as power shovel, dragline, bulldozer, and trailer pumps, must be transported to the site. Roads capable of withstanding this heavy equipment are then necessary, and remote locations may be ruled out.

When the pond is to be formed with two earth dikes, the availability of material for the dikes may be an important factor in selecting the site. Even if local fill dirt is readily available, it may be necessary to locate elsewhere materials that can be adequately compacted to seal the dike from leakage.

The length of the pond is another important factor to be considered. When the pond is to be built with two earth dikes, the test engineer may arbitrarily choose the length of the site, whereas he may find some restriction in choice where the pond must be upstream of a check structure. In general, the length should be great enough to make the sum of the pond end areas a very small percentage of the total wetted area. Since the seepage per unit area through or under temporary dikes can be greater than through a unit area of the bottom or sides of the canal, the effect of the disparity in rates of loss can be minimized by observing this precaution.

As guides to setting the length, a test in a canal with a bottom width 16 feet was made in a pond 1,400 feet long; and in another with a bottom width of 26 feet, the test pond was 800 feet long. The pond end areas in the first canal were about 0.4 percent of the wetted area, and the corresponding figure in the second canal was less than 1.5 percent. The larger the canal the more difficult it may be to select a long site free of turnouts, bridge crossings, and curves.

Where a pond is formed above a check, it may be necessary to use a dike at the upstream end to avoid excessive length and the possibility that the canal grade will result in near-zero depth at the upstream end with design depth at the downstream end. It may be advantageous to pond the section upstream of a check drop in a series of such structures where the distance between any two is not great enough to make the grade effect serious.

Constructing the Ponded Section

Three methods or combinations thereof may be used to create the ponded section. Which of these is used will depend primarily on the size of the canal. First, dams may be built of canvas held in place by a timber at the top and dirt thrown along the edge on the cross section, Figure 1. Such dams are necessarily restricted to small conveyances where the water depth is less than about 2 feet. A heavy-weight canvas treated with waterproofing will usually function with a minimum of leakage. Heavy plastic material may also be used.

In the second method the pond may be constructed with earth dikes at each end, Figures 2 and 3. There seems to be no practical limit to the size of canal in which this method is satisfactory, though the larger the canal the greater must be the care taken in building each dike. For an average size canal, Figure 2, the material is usually pushed into place with a dozer. If the canal is dry during dike construction, the dozer can compact the soil by repeated trips back and forth across shallow lifts. Restricting each lift to 6 or 8 inches will make it possible to secure adequate compaction in this manner. When the canal contains water, care must be taken by the dozer operator not to attempt compaction until the movement of water past the dike has been stopped and the base width is sufficient to resist unrestricted spreading of the fill from the weight of the dozer. Natural soil moisture is usually sufficient to attain reasonable compaction.

One method used to eliminate leakage from the ends of the pond, and thereby reduce experimental error, is to cover the interior sides of the dikes with sheet plastic from 4 to 8 mils thick. The plastic must be placed before filling the pond; the edges can be held in place by shoveling dirt over them, being careful not to puncture the sheet. This treatment is of particular value where the only readily available fill is permeable, such as various types of sandy soil. A dike so constructed will require considerably less yardage for stability than one without a plastic cover.

As the size of the dikes required becomes larger, Figure 3, greater care in construction is advisable. In an unlined or earth-lined canal, a cutoff trench should be excavated along the cross section to allow placement and compaction of selected soil. This trench destroys any thin layer of materials which because of gradation, organic content, and moisture condition, may provide relatively low resistance to horizontal shear forces between the dike and subgrade. It also acts to key the compacted soil above into the subgrade, and the percolation path under the dike is lengthened. Care should be taken to give sufficient base width to the dike, and the slopes of the fill should not be so steep as to encourage slippage of large masses of soil into the pond when the slopes become saturated. The space required for pumping equipment in tests where the pond is filled from a reserve water supply in the canal may dictate the top as well as bottom width of a dike, Figure 3. When earth dikes are to be installed in a concrete-lined canal, it is impracticable to excavate a cutoff trench. The base width of the dike must then be great enough to withstand the hydrostatic pressure in the pond, to make percolation paths so long that leakage is reduced to a negligible amount and piping along the line of contact will not be anticipated.

In the case where water must be passed through a dike to fill a pond, or to pass water to another pond downstream, it will be necessary to install gated culvert pipe. The elevation of this pipe must be under the minimum water surface to be used in the tests, low enough to obtain the advantage of head in transfer of water, but high enough to allow convenient access to the gate wheel. The culvert should be provided with one or more cutoff collars, and the surrounding materials must be carefully compacted to prevent piping along the corrugations.

In small or medium size canals, it is possible to pass water over an earth dike protected with sheet plastic. Thickness of 4 mils or greater will be satisfactory. The entire dike must be covered from upstream to downstream inverts, and the plastic should extend along the canal sides far enough to allow it to be held firmly in place with fill dirt. The joints should be transverse to the direction of flow, and a lap of not less than 1 foot is necessary. If plastic cement is available, overlapping sheets may be joined. Placing of the sheets should proceed from downstream to upstream so that the downstream edge of one sheet will lap over the upstream edge of the next sheet. Installation in this manner will prevent the water from flowing under and tearing a sheet. Flow over the dike should be limited to prevent excessive erosion by the velocity on the downstream side of the dike.

When water is to be stored in a pond above the upstream dike for use in subsequent refilling of the test section, it may be desirable to construct 2 dikes, one to isolate the test reach and another to observe the watertightness of the first dike, Figure 3. If this is done, the dikes should be constructed so that the toes of facing slopes are separated a few feet.

In the third method existing check structures or check drops may be used to pond water, Figure 4A. In the case illustrated, 2 by 6 planking was placed in the stoplog slots. Canvas was draped over the upstream side to cover open joints and to prevent leakage around the ends of the planks. The canvas was held in place along the edges and bottom by soil packed against it. Sheet plastic may be substituted for canvas to cover the joints. If no upstream dike is constructed, the pond will necessarily extend toward the preceding check structure. Such a pond may be quite long and not provide a reasonable uniformity of depth.

If the check is gated, it will probably be necessary to seal each gate against leakage, either by using canvas as above or by packing the gate with a watertight material such as oakum.

A ponding test is performed occasionally along a proposed canal location to develop information for the design. Construction of the pond in this case does not correspond to any of the three types discussed above. Figure 4B shows one such installation in which a 200-foot-long pond was located near the centerline of the proposed canal. The approximate cross section of an 8-foot-bottom-width canal was excavated to the anticipated design elevation. This pond was large enough to yield satisfactory results when properly interpreted. Trial cross sections that have bottom widths not representative of the proposed design, and water and/or excavation depths that are not those of design, should be avoided. Any extrapolation of such dimensions and corresponding seepage rates would be very risky.

Installing Test Equipment

The equipment needed to conduct ponding tests is simple to operate, but precautions should be observed when installing it. The equipment consists of two hook and two staff gages, stilling wells for the hook gages, and in some locations an evaporation pan. A hook and a staff gage are paired for use at the upstream and downstream ends of the pond. The hook gage is a laboratory-type gage and can be read to 0.001 foot with the aid of a vernier. The staff gage is a standard enameled gage frequently used on irrigation projects to indicate water depths, and scaled to 0.01 foot. Figure 5 shows both gages.

Each gage should be referenced by survey to canal elevations so that depths in the pond can be computed for comparison with design depth. The gages are installed on vertical uprights (2 by 4 or 4 by 4 timbers) that have been firmly positioned near the edge of the pond. If the canal is small, the upright can be placed so that an access platform is not needed to read the gages, Figure 6A. When the subgrade is saturated, it may be possible to drive the timber in place, though care must be taken to keep it vertical. To position a 4 by 4, a hole should be augered with a post-hole digger and the timber held vertical while soil is tamped around it.

In larger canals, a walkway will probably be needed to reach the gages, Figure 6B. Under no circumstances should the timber for gages be an integral part of the walkway framing, since repeated trips over the walkway to read the gages would force the upright into the subgrade and destroy any initial correlation of elevations.

Two sets of hook and staff gages should be used. The staff gage reading can serve as a rough check of the hook gage reading, and should the hook gage be accidentally disturbed, the staff gage can be read until a resurvey establishes a new reference on the hook. During windstorms, the water surface of the pond may not be horizontal throughout the length of the pond; therefore, by having gages at each end, average water surface elevations can be determined.

Motion of the water surface makes the accurate vertical positioning of the hook difficult. A stilling well around the hook should be provided to minimize the movement. While elaborate shop-made stilling wells have been used, one or more lengths of 6-inch-diameter stove pipe will serve the purpose quite well. Because of the nominal cost of the pipes, they may be discarded following a test with no great financial loss. The stove pipe is usually nailed to the gage timber at top and bottom. To restrict flow of water into and out of the pipe, the lower end should be crimped nearly shut. A damping effect is thus achieved which greatly reduces the rise and fall of the water in the pipe compared to the fluctuations in the pond. Figure 6A shows one such installation.

There will be evaporation from the pond surface. Whether the rate of loss is sufficient for recognition in seepage rate computations will depend on a number of factors. If a test is performed during warm to hot weather, it may be necessary to measure evaporation. However, in a canal with a high loss rate, 1.5 cfd and higher, correction of the water surface elevation for evaporation may be negligible even during hot weather. On the other hand, in a canal with a low loss rate, the evaporation correction may be significant even during periods of cool weather.

Prior to starting tests the expected evaporation rate should be related to a rough estimate of seepage rate. Good judgment must be exercised by the test engineer in deciding on the necessity for evaporation measurements. Figure 7A shows a temporary installation with an evaporation pan adjacent to the pond, and Figure 7B illustrates a more elaborate setup with a similar pan positioned in the center of a test pond. The latter installation will produce more accurate rates of loss since the water levels in pan and pond are nearly the same, the temperatures of both bodies of water are nearly equal, and the same ambient humidity affects the two surfaces. In many locations evaporation rates may be obtained from a nearby weather station. Good judgment should be exercised to insure that the rates obtained from the station will be representative of those at the test site.

Surveying the Pond

A survey to establish accurately the length and shape of the pond is required. If the pond is isolated with water in the canal, the survey must be done after the tests are completed and the water has drained away. If the pond is built in a dry canal, it will be of advantage to survey before filling the pond to enable simultaneous testing and computing of necessary data from the survey notes. At the conclusion of the ponding tests, computation of seepage rates may proceed without delay.

A comprehensive survey is not necessary for all tests. For instance, concrete-lined canals will probably require pond length measurement but very few cross sections need be measured to establish the as-built shape. If a recently built canal is earth or earth-lined with little erosion or deposition of materials, the cross section may conform closely to the design shape. In this case, the cross section should be checked at a few stations and the length measured.

Where detailed survey is required in older earth canals, cross sections should be taken every 50 feet and elevations measured to within 0.1 foot. The survey should establish the configuration for at least 1 foot in elevation above the anticipated water test level. Any break in the section should be noted in the survey.

If the pond is short, 1,000 feet or less, consideration should be given to taking cross sections every 25 to 50 feet to establish better area and volume accuracy. When the pond is very long, such as one which has been created upstream of a check structure in a canal with a very gradual slope, cross sections every 100 feet may be reasonable.

The age of the canal may also be used as a criterion in deciding at what intervals to cross section. In a new canal with little erosion or deposition, the intervals may be lengthened; in a canal that has been in service many seasons, the intervals required may be short to obtain a satisfactory record of shape. Test personnel must use their best judgment to secure measurements of appropriate accuracy.

Construction survey records can probably be used to establish bench mark elevations on nearby structures. These benches can be used to reference each hook gage point and the staff gages. Along very old canals it may be necessary to run a level circuit from a brass-cap bench mark to temporary bench marks near each end of the pond. The order of accuracy need not be high; a closure on the circuit of 0.03 foot should be satisfactory. A check on the hook elevations may be made when the pond water surface is absolutely still on a calm day.

Observation Wells

The use of observation wells to supplement ponding studies is often worth the added expense. They may be used to log the subsurface materials, to locate the water table, and to observe the slope in hydraulic gradient from uphill to downhill sides of the pond.

The wells should be drilled during construction of the pond before it is filled with water. If the subsurface material is cohesive enough, a 2- to 4-inch hole drilled with a rotary post-hole digger may remain clear for the duration of the tests. Should the hole cave in rapidly, it may be necessary to use driven well points as piezometers, and to forego the opportunity to log the materials.

One or more holes may be located along the pond centerline from the invert to the water table if the table is not an excessive distance below the canal bed. A hole depth of 10 feet will be satisfactory if the water table is not encountered at shallower depths. Any holes along centerline must be backfilled and tamped before filling the pond.

If the pond is located on a hillside, it may be necessary to drill wells on the uphill and downhill sides; in relatively flat terrain, wells on either side of the pond may be sufficient.

Each well should be provided with a reference stake or pipe on which an elevation can be established for correlating all water surface measurements. Water surface elevations in the wells should be determined before the tests begin for comparison with any increase that occurs during the tests. Whenever the hook gages in the pond are read, the water surfaces in the wells should be measured by steel tape or other method from the reference elevation and the measurement recorded.

<u>Filling the Pond</u>

Gravity flow or pumping may be used to fill the test pond. The method will depend on the conditions that prevail at the site and the size of the canal. The following possible courses of action are suggested:

1. Install the downstream control of the pond, fill the site to the operating level by gravity, and then install the upstream control to complete the pond.

2. In a series of ponds, fill the reach of canal by gravity to the upstream dike of the upstream pond, and allow water to flow through gated culverts in the dikes to downstream sites.

3.a. Build both dikes in a dry canal, release water to form a supply reservoir at the upstream dike, and pump the water over the dike into the pond.

3.b. Allow water to flow into the pond by gravity over a dike covered with plastic.

4. After sealing one or more check structures, release water until it flows over the stoplogs at the checks; stop the inflow and, if required, build upstream dikes to complete the ponds.

5. Pump water into the pond from some source not associated with the canal or lateral.

The first suggestion (1) can be applied to small canals or laterals. The larger the canal the more difficult it is to install a control in water at or near the design depth. It is perhaps more difficult to control the flow so that it does not overtop the upstream control of a pond. If it is necessary to refill the pond after a predetermined drop in level, water impounded in the canal can be pumped into the pond.

The second suggestion (2) is applicable where more than one pond is to be tested and the distance between ponds is not excessive. Where there is storage between ponds, it may be pumped as refill for a test pond.

The course of action in 3.a. is commonly used in large canals where it may be impossible because of width and depth to proceed according to (1), or where the volume of water required to fill the canal to a single dike would be excessive from either a practical or an economic standpoint.

The procedure in 3.b. can be used in small to medium size canals where the overflowing head can be limited to prevent erosion. If two earth dikes form a pond, and this procedure is to be used, it is wise to cover both dikes with plastic in case inflow cannot be controlled accurately and rapidly enough to prevent overtopping of the downstream dike.

The suggestion in 4. can be used only when check structures are properly situated. If the canal grade and length between checks are such that the pond depth would be shallow at the upstream end, it may be necessary to install a dike at some intermediate station. In a series of check drops, an appropriate length could be selected for testing and the upstream sections checked for storage in refilling the pond.

The situation which gave rise to suggestion 5. is encountered in ponding along a proposed canal location. Water may be available from a nearby well, stream, lake, or in an extreme case the water could be hauled to the pond in tank trucks.

In any ponding test, it is wise to plan on filling the pond at least twice, and if the test reach is known to leak appreciably, provision should be made for a third filling. Only by repeatedly filling the pond can one be reasonably sure that bank storage has been satisfied and that paths of percolation are as active as in an operating canal.

The starting depth in the pond should be higher than the design depth so that data above and below that level can be secured. This procedure should be followed even though the operating level is below design depth on a project not yet fully developed.

When more than a single filling is required, the refilling may be more difficult than the initial one. Except when gated pipes through the dikes have been provided, water must frequently be pumped into ponds utilizing upstream and downstream dikes unless the procedure in 3.b. is followed. It may be possible to refill a pond upstream of a check structure by gravity flow if there is no upstream dike.

Deciding when to refill a pond will depend on the rate of water surface drop, the depth of the pond, the length of the pond, and the availability of water to accomplish refilling. When the water surface drops rapidly, several tenths of a foot per day, refilling may be necessary by the third day, particularly if the pond depth is 5 feet or less. However, when the rate of drop is less than 0.1 foot per day, a pond of 4-foot depth or more can be allowed to seep up to 2 weeks before considering refilling, if indeed it is refilled at all.

The longer the pond, the earlier refilling must be started since the capacity of portable pumps is usually not large enough to allow rapid filling. Obviously, the more volume to be restored, the longer will be the pumping time. Frequently, water for refilling is stored in a pond upstream of the test section. A daily check on the storage water is advisable to be sure sufficient water remains to replace that lost from the test pond.

Measuring Seepage Losses

With the pond filled and all gages operable, measurement of the rate of drop in the water surface may begin. A suggested form for recording all data during the test is shown in Figure 8. Conventional practice uses the subscripts 1 and 2 for upstream and downstream gages, respectively. The reading of each hook gage is recorded to the nearest 0.001 foot, and the staff gage to 0.01 foot. The extra columns may be used with the Remarks column; comments giving the wind and wave conditions prevailing at the time of reading should be entered. The time of each reading should be recorded to the nearest 5 minutes. This practice will usually enable the observer to read the gages at both ends of a pond within a single 5-minute interval. In small ponds where the seepage rate is high, it may be advisable to record the reading to the nearest 1 minute.

Within a few hours after the initial readings of the gages, test personnel will have reasonable indication of the rate of fall of the water surface. From this knowledge the required frequency of succeeding readings can be determined. If the pond seems to have a high loss rate, readings every 1 to 4 hours may be required; on the other hand, for a pond showing a very slow rate of drop, less frequent readings will be satisfactory.

In one canal test with a seepage loss of approximately 1.3 cfd, gage readings were made about every 4 hours, day and night. On another canal test where the loss rate was less than 0.01 cfd, readings were taken in early morning, midafternoon, and late evening, with no readings between 10 p.m. and 8 a.m. Thus, personnel must decide from test circumstances when to schedule the taking of data.

A graph of water surface elevation versus accumulative time can be readily used in deciding whether additional fillings of the pond will be needed, or if an error in water surface level has been made. An elevation-time diagram is shown in Figure 9. Curve No. 1 for the first filling indicates that the pond either seeps at a rapid rate naturally or that the banks were dry at the beginning of the test, or both. Upon refilling the pond, Curve No. 2 shows that the rate of water surface drop has decreased. Since there is wide spacing between the first two curves, a third filling seems advisable. Curve No. 3 with a decreased rate of water surface drop lies close to that for the second filling and indicates that the seepage loss rates for the range of elevations plotted are nearing stability.

Additional fillings might produce curves slightly to the right of No. 3, but the practice is one with diminishing returns. Considerations of cost and practical value of the data will probably prohibit additional refinement of the test.

Computation of Loss Rates

The computation of loss rates is dependent upon knowing the rate of volume loss and the wetted area of canal affected. There is more than one method for combining these factors, and all require appreciable periods of time to complete. The one described here is a compromise between the most exact method known and a less accurate method which does not make use of a complete pond survey.

The survey notes are used to compute two tables of canal characteristics: (1) the relationship between water surface elevation and water surface width, and (2) the variation of wetted perimeter with water surface elevation.

The first step in compiling these tables consists of accurately plotting the canal cross sections to a scale that will make possible the measuring of water surface widths and wetted perimeters to within 0.1 foot. Noting the range of water surface elevations involved in the tests, water surface widths and wetted perimeters are scaled on each cross section from an elevation just below the lowest test elevation to an elevation slightly above the highest test elevation. The increments of elevation used will depend on the size of canal, depth in the pond, and range of test depths. For shallow canals of short bottom width, it is advisable to compile tables of water surface widths and wetted perimeters for each 0.1 foot of depth. In deeper and wider canals, the increment may be changed to 0.2 or 0.25 foot without seriously affecting the accuracy of computations.

Tables may be compiled with column headings as shown in Figures 10A and 10B. Each column under a particular elevation is averaged for all stations to obtain the representative characteristics for the entire pond. Since elevations measured in the course of the tests will rarely correspond exactly to those in the table, it will be necessary to interpolate between average values for correct water surface widths and perimeters.

The information contained in the tables shown in Figures 8, 10A, and 10B is sufficient for computation of loss rates. To facilitate these computations, another table with headings as shown in Figure 10C is suggested. Data from Figure 8 are entered in Columns 1, 2, 4, and 5. Values in Column 3 are computed from Column 2. To obtain the corrected water surface elevation in Column 6, the correction in Column 5 is added to the water surface elevation measured at the end of each test period. From the table identified as Figure 10A, an interpolated value for water surface width, Column 7, can be found.

In computing the water volume lost, Column 8, a prism of water is defined by an average water surface width, the drop in water surface elevation within the measured time interval, and a longitudinal canal length of 1 foot. The value in Column 8 is the product of the value in Column 7 and the difference in elevations in Columns 4 and 6.

The wetted perimeter in Column 9 is computed from the data in the table of Figure 10B. Since the wetted perimeter decreases as the water surface drops, it is necessary to use a value that is the average of wetted perimeters for beginning and end of the test time interval, Column 10. The desired seepage rate in Column 11 is obtained by dividing the volume lost, Column 8, by the product of values in Columns 3 and 10, adjusted to a 24-hour basis. Stated in mathematical form,

$$\text{Seepage, cfd} = \frac{\text{volume lost (ft}^3\text{) x 24}}{\text{wetted perimeter (ft) x accumulated time increment (hr) x 1 ft}}$$

$$= \text{cubic feet/square foot/day.}$$

To facilitate computations, data in Columns 1, 2, 3, 4, 7, and 9 should be entered on odd-numbered lines, and data in Columns 5, 6, 7, 8, 10, and 11 should be written on even-numbered lines.

Interpretation of Test Data

The main purpose of the ponding test is to produce an accurate seepage rate, but more than this can usually be derived from the test data. By plotting water surface elevation versus time, one can judge the time required for bank storage to be satisfied, and in a general way, the reach of canal can be rated "tight," "borderline," or "leaks like a sieve."

A plot of seepage rate versus depth may indicate whether the greater loss is through sides or bottom of the canal. Referring to the seepage rate-depth diagram, Figure 11, Curve A may result when the water table is so far below the canal invert that seepage rates are unaffected by it, and a greater proportion of seepage is through the bottom. When a curve similar to C is obtained, one can conclude that the rate of loss through the sides is greater than that through the bottom. An intermediate curve, B, indicates either there is no clear difference in rates between bottom and sides or the water table is close enough to the canal invert to influence the rates. Thus, it is important to know the relative positions of canal invert and water table.

Knowledge of the seepage rate alone does not always provide the criterion for deciding whether to line a canal reach. For example, land adjacent to a canal with insufficient natural drainage may have a high water table during the irrigation season or water standing in shallow depressions. It is possible for a ponding test to indicate a loss rate which is anything but conclusive by usual standards in regard to lining the reach; e.g., the loss rate may be from 0.25 to 0.75 cfd. Yet, irrespective of this, it is obvious that the section must be lined to prevent land damage.

It is equally possible to have a loss rate which positively indicates the need for lining, and yet no damage to adjacent lands is visually evident. For this to be the case, the water table must be well below the canal invert, and the subsurface materials must be so permeable that leakage paths are close to vertical.

Sources of Error

Accuracy of loss rates established by the ponding method will depend on the attention given to relatively simple details in preparing for and conducting the tests. Dikes and any turnouts in the pond should be inspected periodically to be sure they are not leaking. If check structures have been used, they likewise should be inspected to be sure stoplogs and canvas are in place. Dangers of leakage around the canvas can usually be averted by timely placement of more fill material at the edges.

Hook or staff gages not provided with stilling wells can yield erroneous readings of water surface levels even when only a light breeze is blowing. Also, it is easy to misread the gage by a full 0.1 foot, but checking the previous reading, or comparing loss increments when upstream and downstream gages are used, will usually prevent the error from being recorded. If such an error is made, it will affect two loss rate computations; the ones in which the erroneous reading is the second, and later the first, of a pair of readings.

As mentioned earlier, the gages should be mounted independently of any access platform. Observance of this precaution may be to no avail if the test engineer repeatedly uses the upright as a support to his equilibrium when approaching or leaving the gage. The urge to so use the upright may be even stronger where no approach platform is present on small laterals and the banks have become slippery.

In any pond which shows a rapid drop of the water surface, elevations must be determined frequently. The longer the time interval between readings, the less accurate will be the average wetted perimeter for the decremental range of elevation.

The survey which establishes reference elevations on all gages is very important. Only closed circuits should be accepted, and the allowable error of closure should be in keeping with the quality of results expected. At some time during the conduct of any test there will probably be a complete absence of a breeze, and the pond water surface will become absolutely still. Check readings on all gages, and particularly on the hook gages, will reveal any differences from the common datum that exist. Adjustments in reference elevations may be in order where the differences are small; if they prove to be large, the survey should be repeated and additional check readings made on a subsequent calm day.

When computing the results from experimental data, many chances for calculator errors will occur. The existence of large errors can be detected by carefully analyzing trends in tabular values. Inordinate increments or decrements unsupported by the data are sufficient cause for suspicion that an error exists. Plotting the experimental data will reveal large errors, but smaller ones could go undetected.

Because of the time required to refill a pond and to repeat a test, the temptation may be to accept seepage rates established in a single filling. When seepage rates are any other than small, this practice could lead to erroneous decisions concerning lining. Until bank storage has been satisfied, the seepage rate will be higher than normal.

SECTION II--SEEPAGE METER

General

The ponding method discussed in Section I is often quite expensive to use and requires considerable time. A device which offers a rapid determination of the general magnitude of seepage losses is the seepage meter. The meter used by the Bureau of Reclamation is a modification of an earlier instrument designed by the Soil Conservation Service, and both are versions of a constant-head permeameter. The meter may be installed in still or flowing water and in the sides or bottom of an unlined canal.

Design of the Seepage Meter

The design principle is based on the assumption that the rate of water loss for an isolated surface area of the canal can be measured. The forces operating on that area must be identical to those acting simultaneously on all adjacent surfaces. With these considerations in mind, the meter in Figures 12 and 13 was designed. The essential components are a cup, a bleeder valve, and a vertical pipe for positioning the meter.

The cylindrical part of the cup is 12 inches high and has a cross sectional area of 2 square feet. A conical top is provided to aid in the flow of air toward the center and the bleeder valve. Water is supplied to the cup through a 3/8-inch copper tube in the top from a plastic bag, Figure 14. All joints are welded to make the cup watertight. Steel straps between the cup and the vertical pipe prevent the pipe from being broken at the joint with the cup. A valve handle extension allows opening and closing the bleeder valve in deep water.

Operation of the Meter

Success in using the seepage meter is to a large extent determined by the skill of the operator. With the bleeder valve open, the meter is lowered into the water with the pipe nearly horizontal; thus, most of the air is freed from the cup before complete submergence. Upon tipping the pipe and cup into the vertical position, the remaining air can flow to the cone center and out through the bleeder valve.

At this stage the meter cup should not have touched the canal bed. The meter cup should be moved while submerged over soil not disturbed by the operator and then placed on the canal surface. From the time the cup edges contact the soil, no horizontal movement should be allowed.

Several methods of forcing the cup into the canal bed have been tried with varying success. The method currently accepted and causing least disturbance to bed materials is to drive the meter into place vertically with a pipe closed at one end, similar to a steel fence post driver. Such a driver must have an inside diameter sufficiently large to fit with ease over the 1-inch standard cap on the top of the meter pipe. While the meter can be installed by one person in this manner, the presence of two saves the energies of both. If two persons are available and the water depth is shallow, each may stand on the meter cup while using the driver. In deep water, driving must be accomplished from a boat or other support. The depth of cup insertion will depend on the canal bed material, but in no case should the cup be driven deeper than 9 inches, and in most cases 6 inches will be satisfactory. Experience has shown that consistent loss rates are attained with this method in 48 hours or less.

It is possible to rock the meter into place by standing on the top of the cup and moving the pipe backward and forward. Inspection by touch of the materials surrounding the cup will probably reveal disturbance sufficient to require replacement of earth against the circumference as a guarantee of an adequate seal. No inspection of the interior is possible, but tests conducted on meters set by this method have shown that a period of a week or more is necessary to stabilize indicated seepage losses. Presumably, this period must elapse before displaced material settles into a position that is stable, though it may not necessarily return to the original state.

After the meter has been installed, the bleeder valve may be closed. As long as the copper tube in the cone remains open, no differential pressure will exist between inside and outside of the cup. If the water is shallow at the time of placement and during a test, it will be possible to connect the copper tube to a flexible plastic tubing from the plastic seepage bag. When the water is deeper, one end of a length of plastic tubing must be connected to the copper tube before lowering the cup into the water, and the other end temporarily fastened to the vertical pipe in a position accessible from the water surface. Should the meter remain unused in the canal for prolonged periods, the bleeder valve must be opened to allow escape of small accumulations of air or gas before starting a test.

To prepare the seepage bag for use, a short length of plastic tubing with a hose clamp is attached to the brass bolt. The clamp must stop all flow from the bag and should be located close to the bolt. The bag may be tested for leaks by partly filling with water and drying the outside surface. The bag should not be filled completely because in the filled condition, the flexed plastic exerts a pressure on the test area within the meter. Before tightening the hose clamp, the air within the bag is forced out. A small bubble remaining will not be harmful, but the major portion should be expelled.

The seepage bag must be weighed. Scales for weighing may have pound or gram units, must be calibrated, have small divisions and maximum range approximately equal to the weight of the water-filled bag to provide accurate weights. After weighing, the bag is connected to the cup. Connection is accomplished with a brass sleeve between the tubing of the cup and seepage bag. The connection is made under water since all lengths of tubing must be free of air. The bag is immersed in the water. A test is begun by simultaneously activating a stopwatch and opening the clamp to release water into the cup.

The depth of water at the meter side should be the only head affecting the seepage bag. No part of the bag should be above the water surface, but it may be hung from the meter support pipe at any elevation below the surface. In canals with high flow velocities, the bag should be protected from impact velocity.

A test is concluded when sufficient time has elapsed for most of the water to flow from the bag through the cup and isolated canal area. The clamp is closed, and the stopwatch stopped. The bag is disconnected from the cup, the outside is dried, and the bag and contents then weighed. The difference between starting and final weights converted to volume is a measure of the seepage loss.

Computation of Loss Rates

Seepage meter data may be recorded on a sheet such as Figure 15. The approximate station of each meter and location in bottom or side of the canal is recorded. Average air and water temperatures during the test should be noted. Recording the depth of water is important for relating seepage rates to the canal design depth; if a test is conducted with a water surface below design depth, the seepage rate for design depth would probably be higher than that measured, and vice versa.

Scales used by the Bureau of Reclamation for weighing the seepage bag are calibrated in grams. This gram weight is converted to an equivalent volume in cubic feet by the following formula:

$$\text{Cubic feet} = \frac{(\text{loss in grams})}{(453.6)(62.4)} = \frac{(\text{loss in grams})}{28{,}305}$$

With the loss in cubic feet, and the net time of the test, the rate of loss is computed.

$$\text{Seepage rate, cfd} = \frac{\text{loss } (\text{ft}^3) \times 24 \text{ (hr)}}{\text{test area } (2 \text{ ft}^2) \times \text{test duration (hr)}}$$
$$= \text{cubic feet/square foot/day}$$

Sources of Error

There are many sources of errors in seepage meter work. Some can be controlled or eliminated, while others occur in spite of the best precautions to avoid them. In the category of those which can be controlled or eliminated are:

1. Inaccurate weighing of the plastic bag, before and/or after test.

2. Filling the bag too full of water so that the plastic exerts a force on the enclosed body of water.

3. Leakage of water from the plastic tubing at the bag, connector, or cup.

4. Inaccurate timing of the test period.

5. Installation of the meter resulting in a poor seal around the cup or excessive disturbance of the bed material within the cup.

6. Using a plastic bag with a leak.

7. Placing the plastic bag so that it is under the influence of velocity in flowing water.

8. Positioning the plastic bag so that it becomes exposed above the water surface during the test.

9. Forgetting to close the valve on top of the cup.

10. Disturbing the test area by walking on it prior to installing the meter.

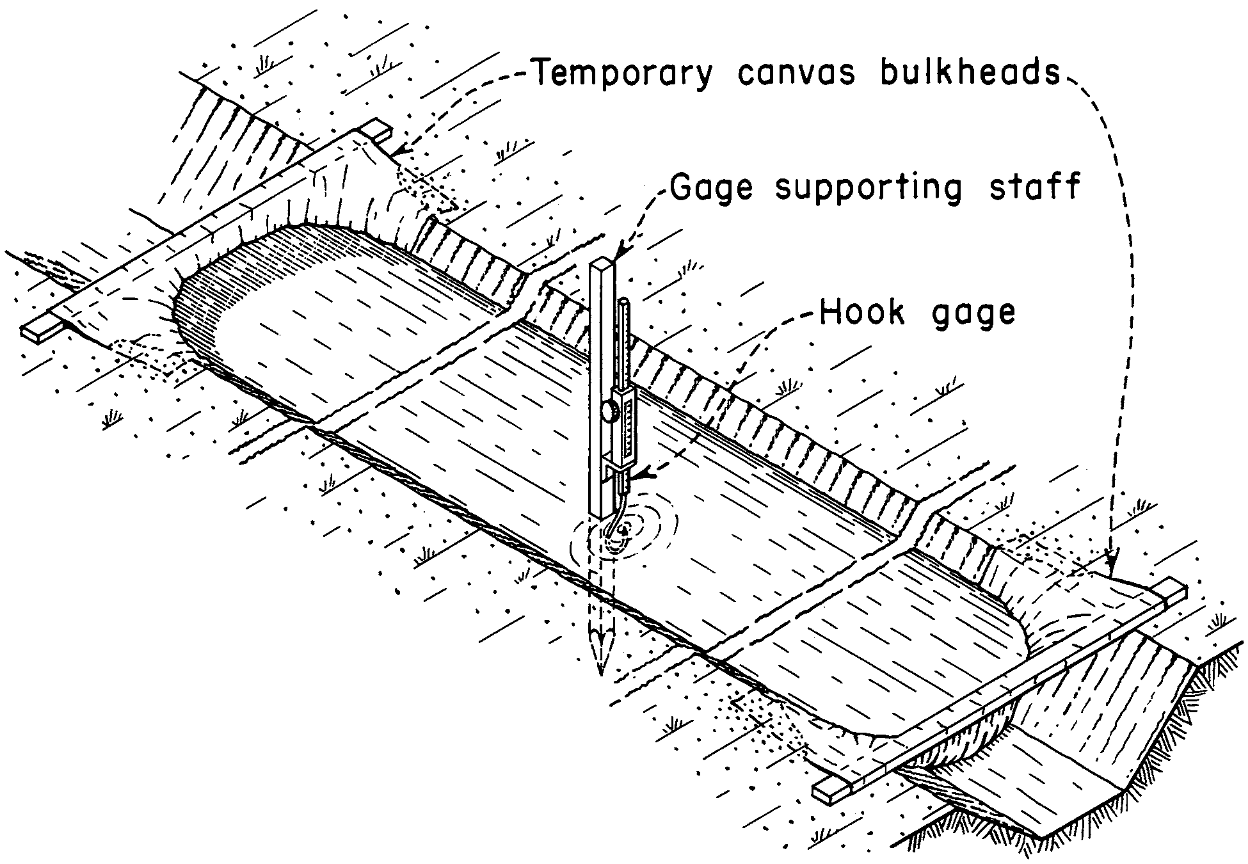
11. Driving the meter so deep that bed materials in the cup are forced against the top.

Among those which may occur even with reasonable care are:

1. Leakage from the cup around stray sand or gravel pockets.

2. Locating the meter in an area of bed materials not truly representative of the general soil types.

3. Installing the meter over a source of inflow to the canal.



MEASURING SEEPAGE LOSS IN IRRIGATION CANALS
POND CREATED BY TEMPORARY CANVAS BULKHEADS

Measuring Seepage Loss In Irrigation Canals
Building Dike In Canal With Bulldozer

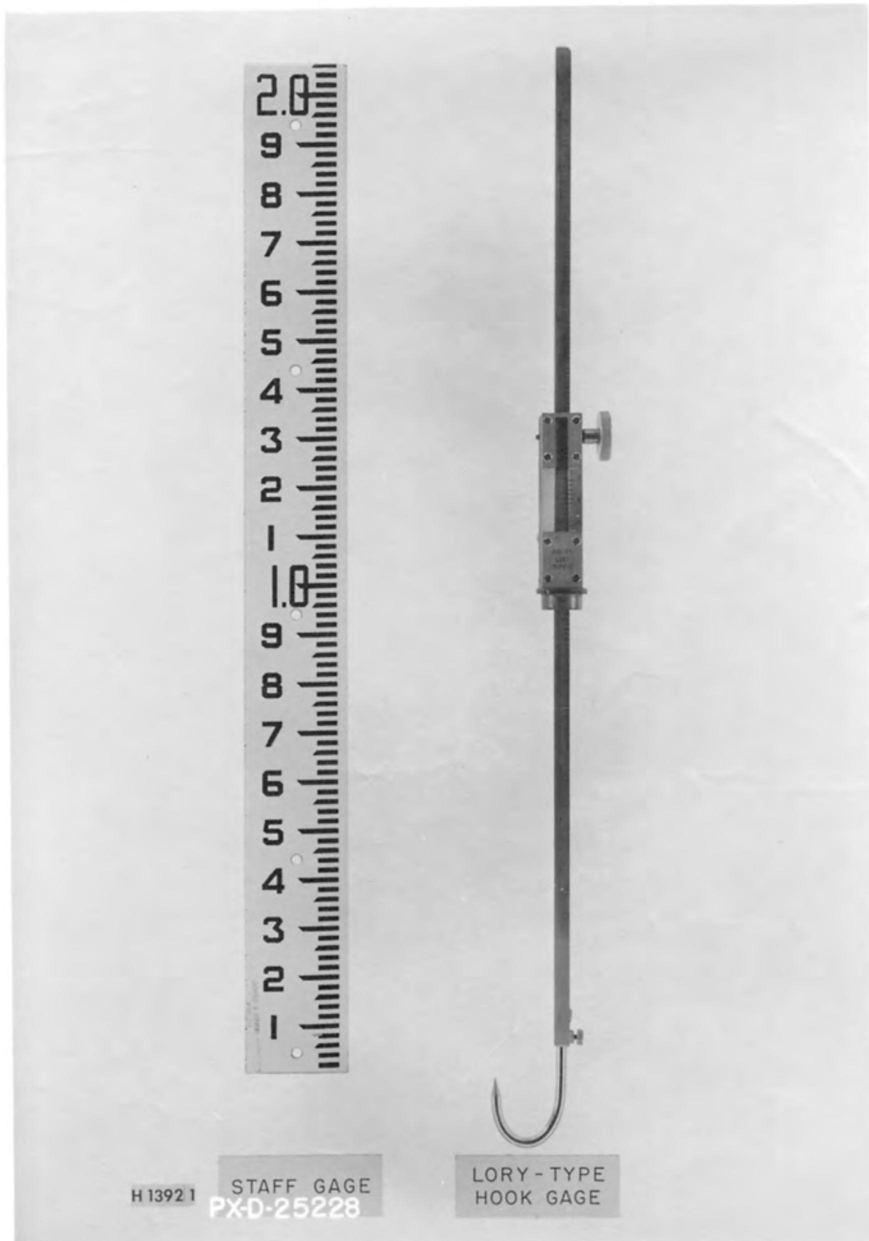
Figure 2
HYD 459

Measuring Seepage Loss In Irrigation Canals
Double Dike Installation Showing
Four Pumps For Filling Pond

A. Check Drop Used At Downstream
End Of Pond

B. Test Pond Near Centerline of
Proposed Canal

Measuring Seepage Loss In Irrigation Canals
Pond Control With Check And Pond On Proposed Canal Centerline



Measuring Seepage Loss In Irrigation Canals
Hook And Staff Gages

A. Hook Gage In Stilling Well Mounted
Close To Canal Bank

B. Hook And Staff Gages Mounted
Separate From Access Platform

Measuring Seepage Loss In Irrigation Canals
Installation Of Hook And Staff Gages

A. Evaporation Pan Set On Dike Of Seepage Pond

B. Weather Bureau Class A Evaporation Pan In Center Of Test Pond

Measuring Seepage Loss In Irrigation Canals
Evaporation Pan Installations

Form DCT-19
11-49
Bureau of Reclamation

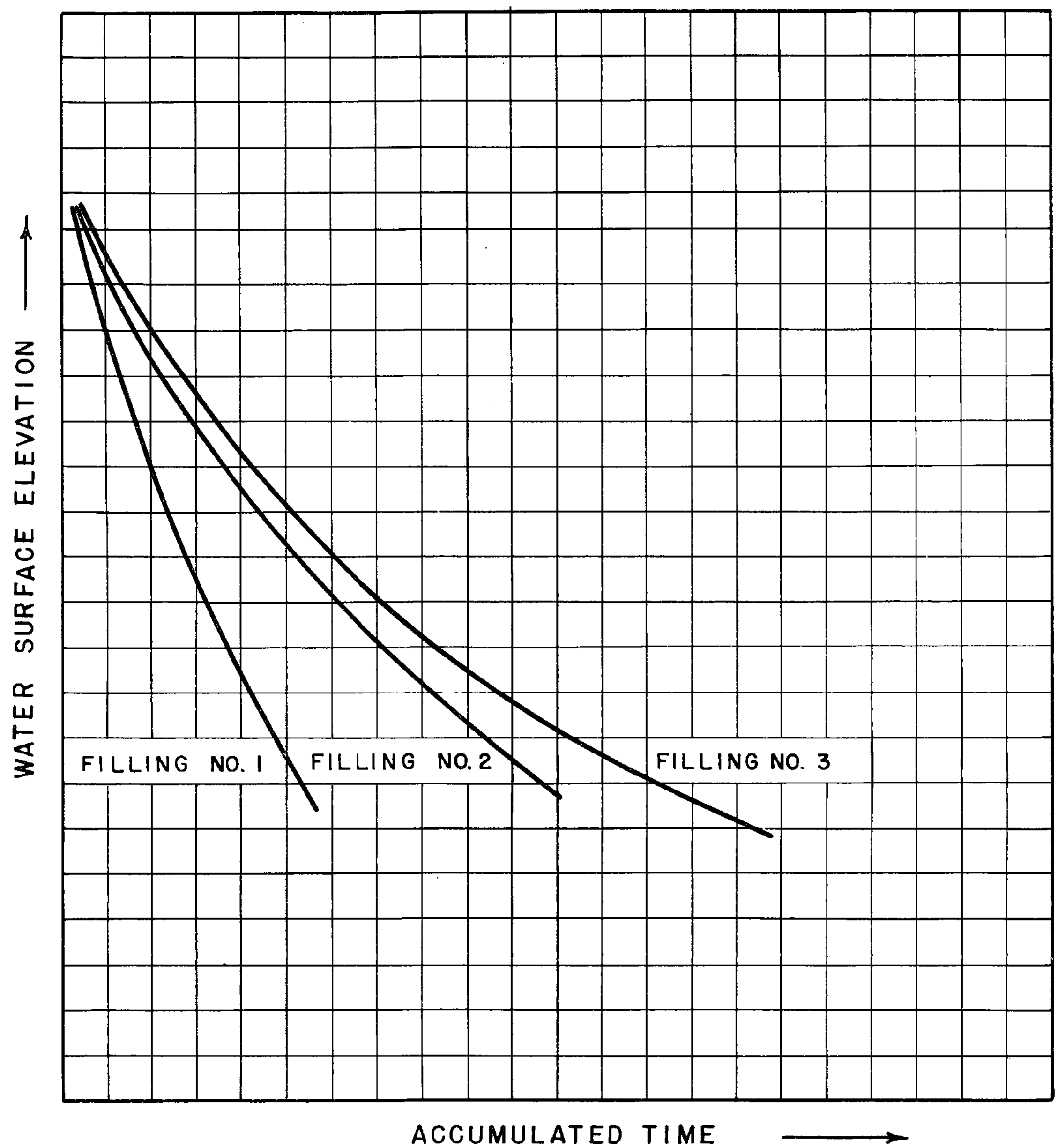
SEEPAGE LOSS DATA

Canal ____________________ Hook gages: sta.________ and sta. ________

Dike: sta.________ and sta.________ Staff gages: sta.________ and sta. ________ Recorder: ____________

Date	Time	Hook		Staff		Temperature						Remarks
		H_1	H_2	S_1	S_2	Air	Water					

FIGURE 8



MEASURING SEEPAGE LOSS IN IRRIGATION CANALS
WATER SURFACE ELEVATION vs. ACCUMULATED TIME

FIGURE 10

Canal ______________________ Pond No. ____________________

Station	Water Surface Widths for Various Elevations									
	1909.1	1909.1	1909.2	1909.3	1909.4	1909.5	1909.6	1909.7	1909.8	1909.9
116+00										
+50										
117+00										

A. Table of water surface widths

Canal ______________________ Pond No. ____________________

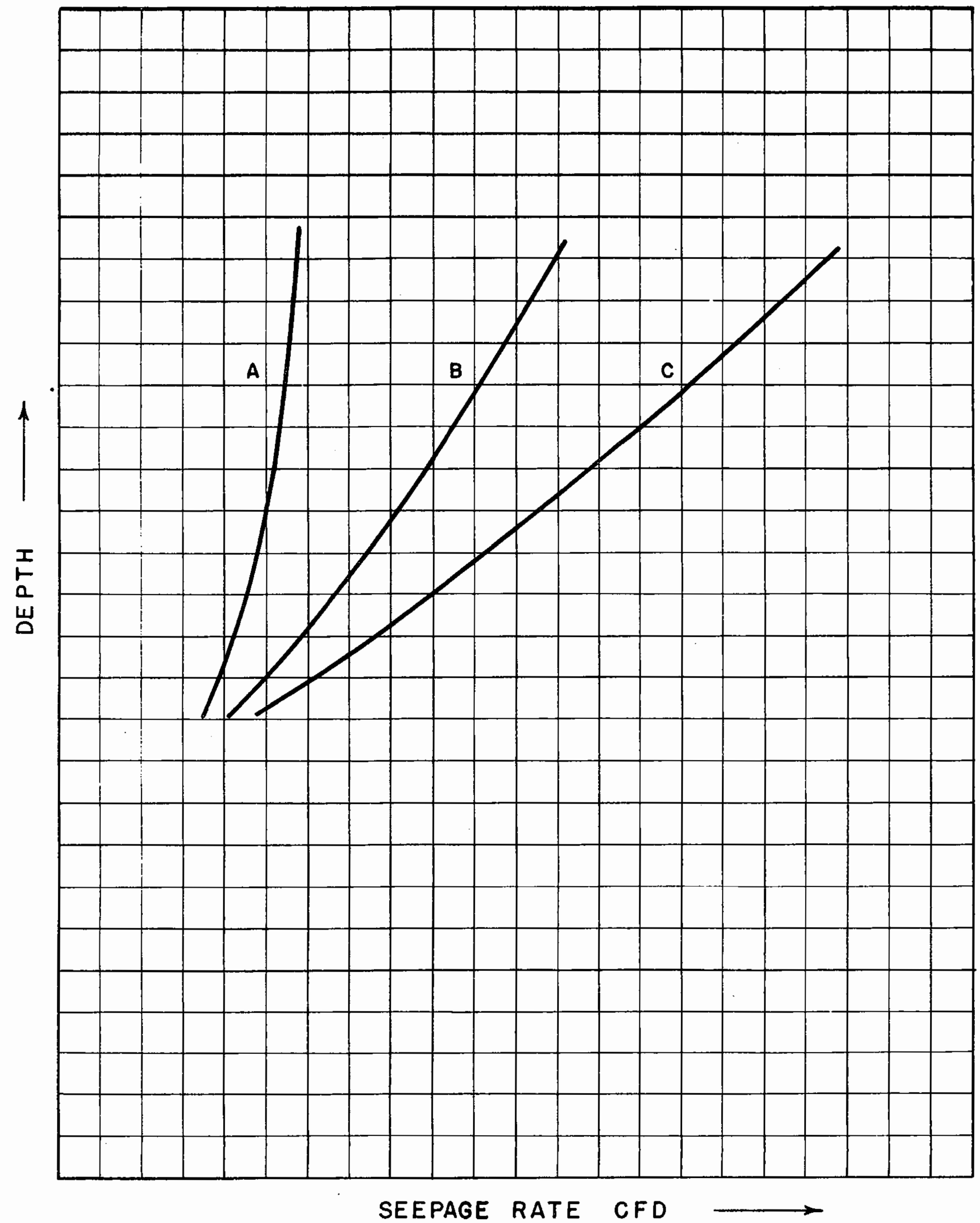
Station	Wetted Perimeters for Various Elevations									
	1909.1	1909.2	1909.3	1909.4	1909.5	1909.6	1909.7	1909.8	1909.9	1909.9
116+00										
+50										
117+00										

B. Table of wetted perimeters

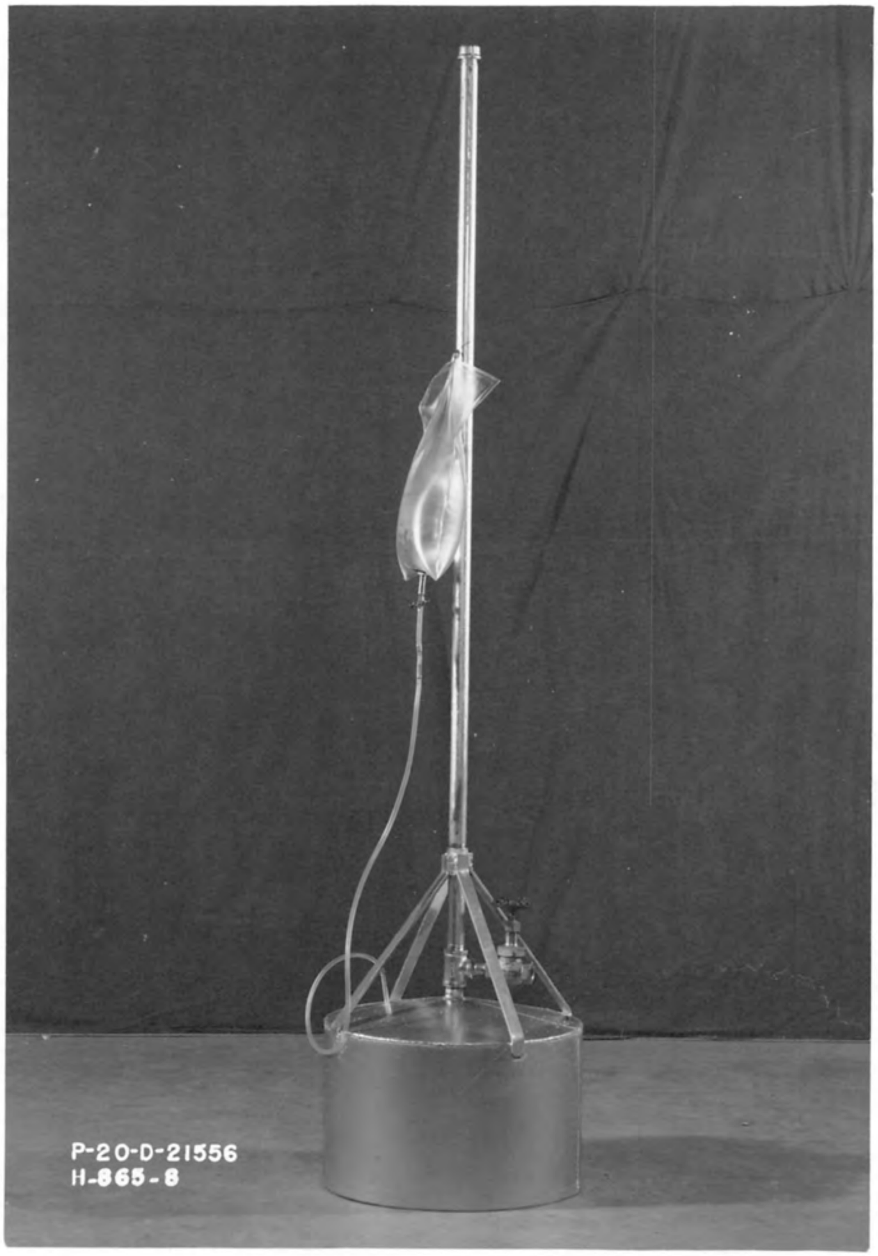
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Date	Time	Accumulated time, hours	Water surface elevation	Evaporation correction, feet	Corrected water surface elevation	Water surface width, feet	Volume lost, cubic feet	Wetted perimeter, feet	Average wetted perimeter	Seepage rate, cfd

C. Table for computing seepage losses

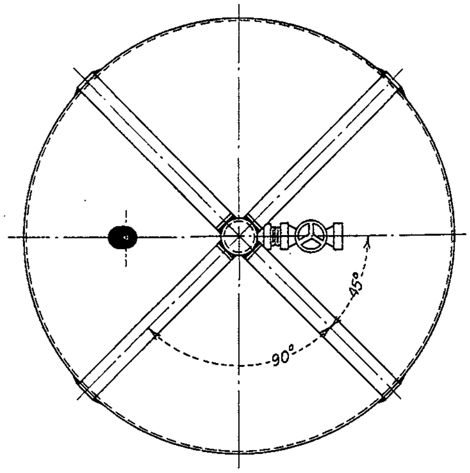
Measuring Seepage Loss in Irrigation Canals
Seepage Loss Computation Sheets



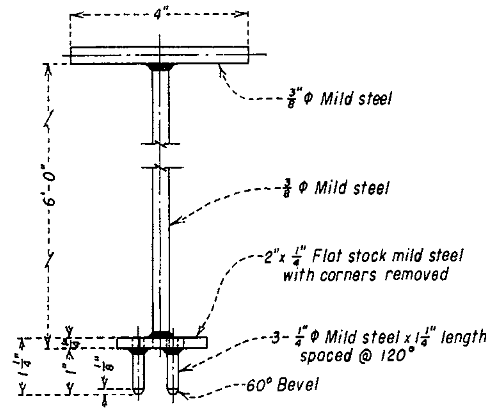
MEASURING SEEPAGE LOSS IN IRRIGATION CANALS
DEPTH vs. SEEPAGE RATE



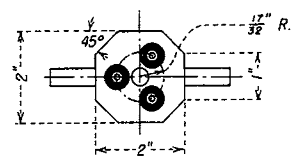
Seepage Meter With Plastic Bag
For Use In Unlined
Operating Canals



PLAN



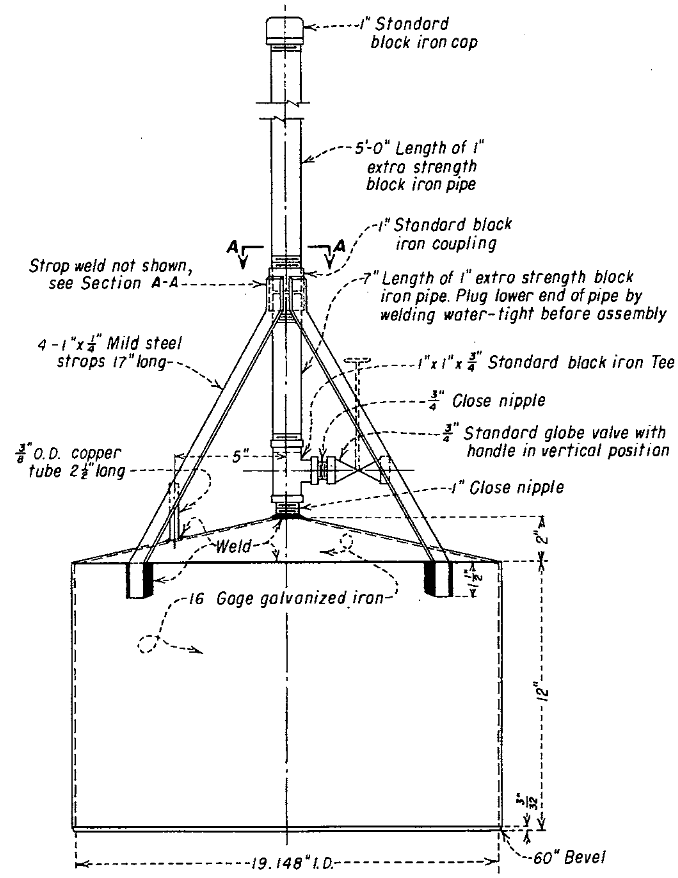
ELEVATION



BOTTOM VIEW

VALVE HANDLE EXTENSION

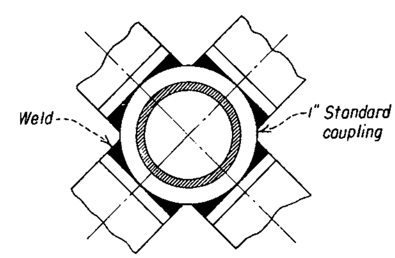
SCALE OF INCHES



ELEVATION

SEEPAGE METER

SCALE OF INCHES



SECTION A-A

NOTES

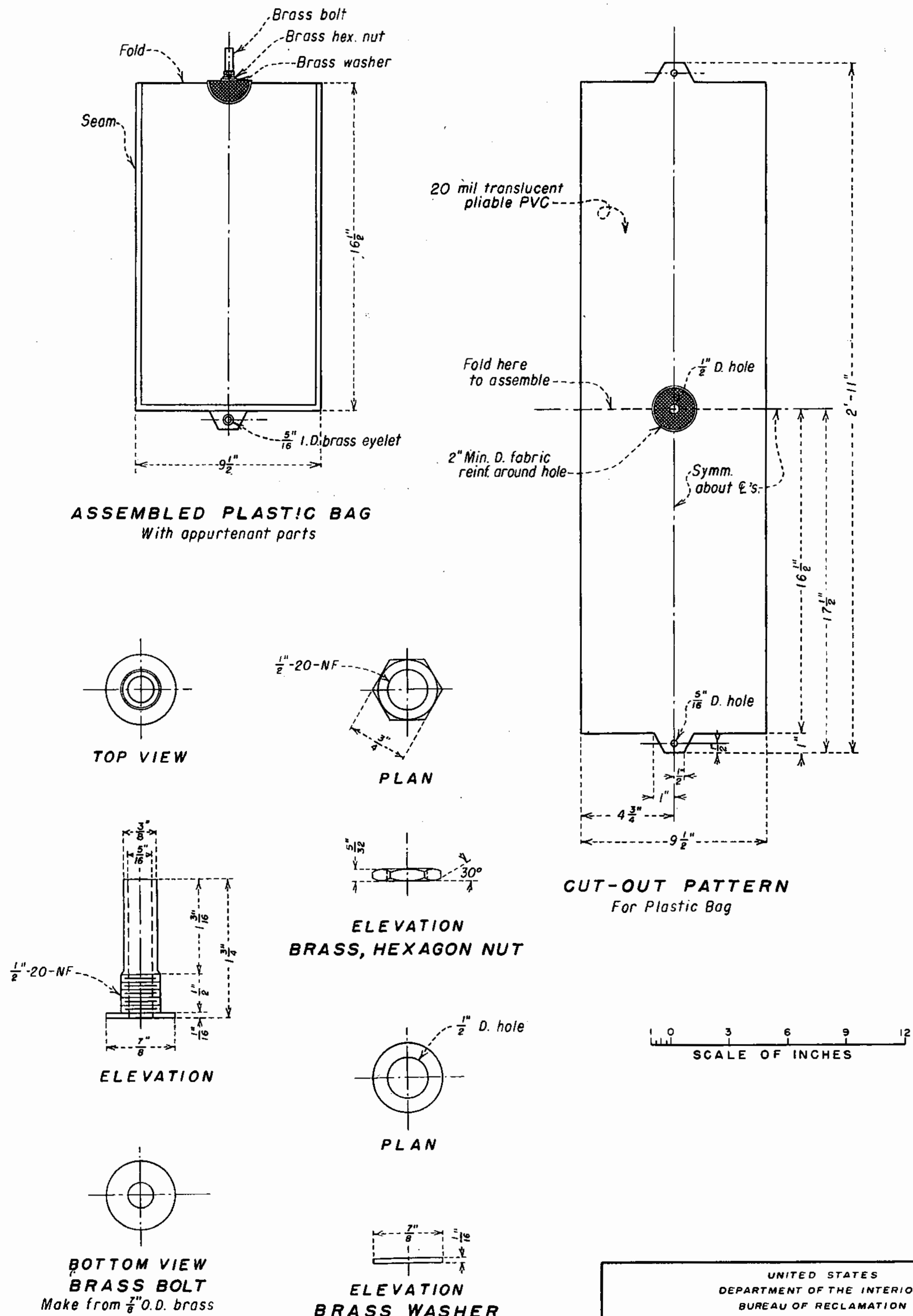
Paint all exposed parts, except brass, with aluminum paint.
All welds on seepage meter, except welds on straps, to be water-tight.
All parts of valve handle extension to be welded together using appropriate size welds.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COST CANAL LINING PROGRAM

SEEPAGE METER
AND VALVE HANDLE EXTENSION

DRAWN. A.J.A.	SUBMITTED. Charles W. Thomas
TRACED. E.V.M.	RECOMMENDED.
CHECKED. R.S.-C.O.D.	APPROVED.
DENVER, COLORADO — APRIL 26, 1950	8030-RH-1

640
~~250~~



640
250

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COST CANAL LINING PROGRAM

PLASTIC BAG WITH BRASS FITTIN
FOR SEEPAGE METER.

DRAWN A.J.A.	SUBMITTED Charles W. Thom
TRACED E.V.M.	RECOMMENDED
CHECKED RS.-C.O.D.	APPROVED
DENVER, COLORADO—APRIL 21, 1950	8030-RH-2

Form DCT-27
11-49
Bureau of Reclamation

SEEPAGE METER DATA SHEET

Project__________ Canal__________ Sheet ____ of ____

Meter Depth__________ Meter Area__________ Weather__________

Variation of WS from Normal__________ Design Capacity__________

Percent Cut__________ Fill__________ Soil Type__________

Observer__________ Date__________

Station	Temperature		Water	Water Bag Weights			Time (Min.)			Seepage Loss	Remarks
	Air	Water	Depth	Initial	Final	Loss	Initial	Final	Net	c.f./s.f./24 hrs.	

FIGURE 15