

BUREAU OF RECLAMATION
HYDRAULIC LABORATORY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

**MASTER
FILE COPY**

DO NOT REMOVE FROM THIS FILE

PROGRESS REPORT--INVESTIGATION OF A SEEPAGE
METER DESIGNED BY THE AGRICULTURAL RESEARCH
SERVICE--LOWER COST CANAL LINING PROGRAM

Report No. Hyd-529

Hydraulics Branch
DIVISION OF RESEARCH



OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

June 30, 1964

CONTENTS

	<u>Page</u>
Abstract.....	ii
Foreword.....	iii
Summary.....	1
Introduction.....	2
Equipment and Procedures.....	2
Meter Description.....	2
Test Procedure.....	3
Seepage Calculation.....	4
Investigations.....	6
Seepage Tests in Laboratory Seepage Tank.....	6
Seepage Tests in the Test Pond.....	7
Future Investigation.....	9
Conclusions.....	9
 <u>Table</u>	
1 Tests of ARS Seepage Meter in Seepage Tank.....	10
2 Tests of ARS Seepage Meter in Test Pond.....	11
3 Comparison of Seepage Measurements--Test Pond.....	12
 <u>Figure</u>	
1 Seepage Meter used in Laboratory and Field.....	13
2 Schematic Diagram of ARS Seepage Meter.....	14
3 ARS Seepage Meter Installation in Pond Test Section.....	15
4 Seepage Calculation Graphs.....	16

ABSTRACT

A seepage meter designed by the Agricultural Research Service and the proposed operating procedure were investigated for accuracy and dependability. Laboratory studies in a tank and simulated field tests in a canal-shaped pond were performed to evaluate the meter. The meter, consisting of a 10-inch-diameter bell which is pressed into the earth to isolate the test area, and an adjustable height reservoir to supply water to the test area, is operated on a falling-head principle rather than on the constant-head principle used in the Bureau of Reclamation meter. Seepage measurements made under controlled conditions were found to be repeatable. Simulated field measurements produced apparently satisfactory results, but more data are required before meter accuracy and dependability can be stated.

DESCRIPTORS--Seepage/*canal seepage/*seepage losses/meters/leakage/ponding tests

IDENTIFIERS--Seepage meters/variable head/Bureau of Reclamation/

FOREWORD

The studies discussed in this report were performed during October and November 1962 under the direction of J. C. Schuster. Laboratory and field experiments were made by P. C. Knodel and the data were analyzed by P. C. Knodel and C. E. Brockway.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Office of Chief Engineer
Division of Research
Hydraulics Branch
Special Investigations Section
Denver, Colorado
June 30, 1964

Report No. Hyd-529
Author: C. E. Brockway
Checked by: J. C. Schuster
Reviewed by: A. J. Peterka
Submitted by: H. M. Martin

PROGRESS REPORT--INVESTIGATION OF A SEEPAGE
METER DESIGNED BY THE AGRICULTURAL RESEARCH
SERVICE, U. S. DEPARTMENT OF AGRICULTURE

SUMMARY

The purpose of this study was to investigate the accuracy and dependability of the ARS (Agricultural Research Service) type seepage meter. This meter utilizes a variable-head technique for seepage measurement. The study was carried out as part of the Lower Cost Canal Lining Program for evaluating methods of determining seepage losses.

Seepage measurements were made with the ARS meter in the laboratory and in a field test pond. The seepage rates indicated by the ARS meter in the laboratory were compared with seepage rates obtained in a seepage tank. Field measurements were compared with seepage rates determined by ponding and by Bureau of Reclamation seepage meters which use a constant-head principle.

Data collected thus far in this study are not sufficient to warrant any conclusions as to the accuracy of the ARS meter but a limited number of laboratory tests indicate that the meter may measure about 25 percent lower than the actual seepage rate. Seepage rates measured successively at one placement with the ARS meter, under controlled laboratory conditions, are repeatable.

Seepage measurements with the ARS meter, using the variable-head technique, may be made somewhat faster than the Bureau seepage meter. Additional laboratory and field studies are required before the accuracy and reliability of seepage measurements with the ARS meter can be determined. Further tests of the meter in an improved laboratory seepage tank and in a field test pond will be conducted.

INTRODUCTION

With the increasing need for conservation of irrigation water and the subsequent use of various types of canal lining for reducing seepage, many methods and devices for determining seepage have been investigated. The ponding method which is considered the most accurate method of measuring seepage is both time consuming and costly. Inflow-outflow methods are subject to considerable error unless precise equipment is used to measure all flows.

Various types of seepage meters have been introduced in an effort to find a fast, economical means of determining seepage rates from existing and operating canals. Most bell-type seepage meters now in use require that the pressure conditions on the soil outside the bell be duplicated inside the meter. The flow from the meter through the area enclosed by the cylindrical bell is considered to be the seepage. Several constant-head devices such as the Mariotte siphon and the submerged plastic bag have been used to maintain the outside head conditions inside the meter.

The seepage meter designed by the Agricultural Research Service utilizes a variable head technique whereby seepage is determined from flow rates into or out of the seepage meter under deliberately created head differences between the seepage meter interior and the surrounding water surface. Variable head devices for measuring seepage offer several advantages over the constant-head meters. The need for exact duplication of the canal head inside the meter is eliminated. Using a constant-head device, seepage calculation is based on a single volume or time determination whereas, with the variable head device, seepage calculations are based on a number of head and time readings. The variable head device thus gives the advantage, statistically, of more reliable results. Also, using the variable head procedure, the hydraulic conductivity of the underlying soil and the hydraulic gradient can be determined. This progress report outlines the initial phases of the investigation of the ARS seepage meter.

EQUIPMENT AND PROCEDURES

Meter Description

A seepage meter was constructed for study, as shown in Figure 1, from a drawing similar to Figure 2 furnished by the Agricultural Research Service. The meter includes a seepage bell, a falling level reservoir, an inverted U-tube manometer, and connecting tubes for measuring the difference in water level between the canal and the reservoir. The conical lid of the 10-inch-diameter bell is removable in order to minimize the disturbance to the soil when

the lower part of the bell is inserted. Three toggle bolts are used to fasten the lid to the cylindrical portion of the bell. The seal is accomplished between these two parts in the ARS meter by soft rubber U rings (see Figure 2). The meter bell constructed for this study was sealed by an "O" ring, Figure 1B. The falling level reservoir is connected to the bell through a valve and 1/2-inch flexible, transparent plastic tubing. A 1/4-inch flexible tube connects the bell to one side of the manometer. The other side of the manometer is connected with 1/4-inch tubing to a 6-inch length of perforated 1/2-inch galvanized pipe mounted on the outside of the meter bell (in effect this leg is connected to the canal pond). The inverted U-tube manometer provides a convenient method for determining the head difference between the water inside and outside the falling level reservoir. Since one side of the manometer is connected to the seepage bell and the other side to the open pond or canal, the manometer differential is always equal to the head difference, H, or the head on the soil inside the seepage bell.

For this study a 3-3/4-inch-inside-diameter transparent plastic cylinder was used for a falling level reservoir. The cylinder was mounted with a sliding bushing to a rod driven in the canal bottom. This allowed the reservoir to be positioned at any desired height on the rod.

Test Procedure

The cylindrical portion of the bell was forced into the soil by hand, until the upper rim of the cylinder was within about one-half inch of the soil surface. The conical lid was then fastened to the cylinder and the bell was left undisturbed with the valve open and the reservoir disconnected for a period of 2 to 3 hours to allow the seepage flow conditions through the bell to become stabilized. In preparation for the test, the reservoir was lowered and about half submerged in the water but not connected to the bell.

With the valve open, water was drawn by use of a hand vacuum pump to a convenient height in the manometer located above the tank or pond water surface level, Figure 3. The reservoir was then connected to the meter bell, and the reservoir was raised until the water level was 4 or 5 inches above the tank or pond water surface.

After the initial fluctuations of the water levels in the manometer had ceased, readings were taken on both sides at regular time intervals for a convenient length of time depending on the seepage rate. The total time required for each seepage measurement is a function of the diameter of the falling level reservoir and the soil seepage rates. About 15 minutes are required for a seepage

measurement in a soil with a seepage rate of 3 to 5 cfd (cubic feet per square foot per day). Reservoirs with diameters larger or smaller than 3-3/4 inches can be used to change the time required for the measurement in soils having higher or lower seepage rates.

The outflow from the meter bell can be assumed to consist of two components, seepage and leakage. Seepage is defined as the outflow of water from the meter bell caused by the head differential between the soil inside the bell and the ground-water table or some other surface of lower potential below the canal bottom. For a given water depth, seepage changes through the meter bell caused by slight head changes on the soil inside the meter are considered negligible. If the differential between the head on the soil inside the meter bell and the surrounding soil is positive, then leakage occurs from the meter to the soil outside the meter. If the differential head is negative, then the leakage is negative, or into the meter. At some differential head, H_b , the leakage into the meter will equal the seepage and the net outflow from the meter will be zero. This balanced flow condition is reached when the water surface in the falling level reservoir has stabilized at a minimum level.

The balanced head, H_b , can be determined by two methods. In the first method the water level in the reservoir is allowed to stabilize with the valve open and the differential head is read on the manometer. This method requires considerable time. The preferred method, which is also faster, consists of closing the valve on the meter bell, preventing flow from the reservoir, and allowing the manometer differential to stabilize for about 10 minutes. The manometer will stabilize at a differential where the leakage and seepage are in balance or where the net outflow is zero.

Seepage Calculation

To calculate seepage by the variable-head technique, it was necessary to obtain a series of readings of both sides of the manometer versus time. From these measurements, the seepage was calculated by the methods outlined in a paper by Herman Bouwer and R. C. Rice titled "Seepage Measurements in Seepage and Recharge Studies" in the Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Volume 89, No. IR1, March 1963.

Two methods of calculating seepage by the variable or falling-head technique are outlined by Bouwer and Rice. The first equation, referred to as the logarithmic equation is,

$$I_{s,0} = \frac{(2.3)(1440)H_b R_v^2}{t R_c^2} \log \frac{H_0 - H_b}{H_t - H_b} \quad \text{Equation (1)}$$

where,

H = difference in water level between falling level reservoir and canal or the manometer differential--feet

$I_{s,0}$ = seepage rate at H = 0, cfd (cfd = cubic feet per square foot per day)

H_b = H at balanced flow conditions--feet

H_0, H_t = H at time $t = 0$ and t , respectively--feet

R_c = inside radius of seepage meter bell--feet

R_v = inside radius of falling level reservoir--feet

t = elapsed time from start of test--minutes

Equation (1) can be written

$$I_{s,0} = \frac{(2.3)(1440) H_b R_v^2}{R_c^2} \log \frac{H_0 - H_b}{H_t - H_b} \frac{1}{t}$$

and the value of $\frac{H_0 - H_b}{H_t - H_b}$ for successive readings plotted against the corresponding time "t" on semilog graph paper.

Figure 4A shows a plot of $\frac{H_0 - H_b}{H_t - H_b}$ vs "t" for a typical seepage measurement. The slope of the best-fit line gives the average value of the ratio $\log \frac{H_0 - H_b}{H_t - H_b} \frac{1}{t}$. The line shown in Figure 4A has a slope of 0.015.

Using a meter bell radius, R_c , of 0.411 foot, a reservoir radius, R_v , of 0.156 foot and a measured H_b of 0.885 foot, substitution into Equation (1) gives the seepage rate $I_{s,0} = 6.34$ cfd.

The second procedure, or graphical seepage calculation, utilizes the equation,

$$I_{s,0} = \frac{1440 R_v^2}{R_c^2} \left(\frac{dH}{dt} \right)_{H=0} \quad \text{Equation (2)}$$

The term $\left(\frac{dH}{dt}\right)_{H=0}$, the change in head with respect to time when the differential head is zero, was evaluated graphically, Figure 4B. Readings of the side of the manometer connected to the meter, and the side connected to the open pond were plotted against time. The intersection of the meter and pond manometer curves indicates the time at which $H = 0$. The divergence of the tangents to the two curves at the point of intersection is $\left(\frac{dH}{dt}\right)_{H=0}$. The value of $\left(\frac{dH}{dt}\right)_{H=0}$ was determined by measuring the vertical distance \bar{H} , between the two tangents at a point one time unit to the right of the intersection as outlined in the procedure given by Bouwer. The measurement of \bar{H} at one time unit to the right of the intersection is actually a graphical determination of the sum of the absolute values of the tangents to both curves. By substitution, Equation (2) can then be written $I_{s,0} = \frac{1440R_v^2}{R_c^2} \bar{H}$. Figure 4B shows the determination of \bar{H} for the test indicated in Figure 4A. \bar{H} was found to be 0.032 feet per minute. Substituting \bar{H} into Equation (2) gives $I_{s,0} = 6.64$ cfd. The value of $I_{s,0}$ computed from Equation (2), 6.64 cfd, compares favorably with the value computed from Equation (1), 6.34 cfd.

The selection of the method of computation depends on the information required and the preference of the investigator. If it is desired to extend the computation to determine the hydraulic conductivity or permeability of the soil, it is necessary to determine a hydraulic gradient and H_b must be measured. If H_b is known, the theory can be extended and the hydraulic conductivity of the soil computed from equations given by Bouwer but not outlined in this report. If only the seepage is required, H_b need not be evaluated, and the graphical intersection method is best suited. Both methods are based on best-fitting curves through observed points giving the advantage, statistically, of more reliable results; also the seepage determination is not based on one measurement of head. However, the time required for measurements and calculations using the graphical method, Figure 4B, are considerably reduced over the logarithmic or variable-head Equation (1).

INVESTIGATIONS

Seepage Tests in Laboratory Seepage Tank

Laboratory seepage tests with the ARS meter were made in a 55-gallon drum 22-1/2 inches in diameter and 33 inches deep, having a spigot

at the bottom. Medium-coarse sand was laid in the bottom one-third of the drum, and a medium sand with a 50 percent size of 0.25 mm (millimeter) was laid to within approximately 1 foot of the top. The drum was nearly filled with water and the level was held constant by adjusting the spigot and inflow and allowing the level to stabilize. Outflow from the spigot at the bottom of the barrel was measured in a calibrated glass beaker. The ARS meter was installed in the drum and left undisturbed for the entire test series.

The seepage indicated by the ARS meter from 11 tests in the drum was calculated using both the logarithmic and graphical intersection methods, Table 1. The average seepage from the drum was 8.28 cfd whereas the average seepage indicated by the ARS meter in the drum was 6.17 cfd. Seepage rates calculated using the two different equations agree quite well, but the average seepage indicated by the meter is about 25 percent below the measured seepage from the drum. This may have been caused by one or more of several factors. The ratio of the diameter of the drum to the diameter of the seepage bell was 2.2, whereas, the necessary ratio indicated by Bouwer to insure no interference with the flow net by the drum is about 4.0. Leakage along the side of the drum may have caused measured seepage rates (tank seepage) to be too high. Ridges around the circumference of the drum made difficult the determination of the actual seepage area. For these tests, the area was computed from the minimum diameter and the larger area corresponding to the diameter at the ridges was not used. The computed seepage area may therefore be as much as 9 percent less than the effective seepage area.

Because of the above considerations, seepage comparisons between the ARS seepage meter and the laboratory test tank used in this study should not be considered as representative. However, the tests did show that seepage measurements with the ARS meter are consistent and can be repeated for the same meter setting.

Seepage Tests in the Test Pond

Measurements with the ARS seepage meter were conducted concurrently with electrical logging tests and ponding tests in a 75-foot-long pond of trapezoidal cross section at the Denver Federal Center in November 1962. The water surface in the test pond was regulated to a near constant level by means of a float valve which allowed water to enter the pond to replace that lost by seepage. The quantity of inflow to the pond was measured with a watermeter, and the water surface elevation was measured with a water stage recorder and staff gage. The average seepage from the test section was determined by dividing the measured inflow by the wetted area of the pond. Figure 3 shows the test section and seepage meter installation.

A trench 5 feet wide by 11 feet long by 5 feet deep had been excavated in the test pond and backfilled with sand. This trench was prepared in conjunction with the electric logging operations to determine whether or not seepage could be detected in the pond using electrical probes. Seepage from the sand trench was from 7 to 27 times greater than the seepage in the remaining areas of the pond, as indicated by Bureau of Reclamation type seepage meters.

Twenty-three seepage loss measurements were made with the ARS seepage meter in the test pond. The results, obtained by computing the seepage from the two different equations as outlined by Bouwer, agree very well as shown in Table 2. Some of the tests showing low seepage rates were not continued long enough to determine the seepage by the graphical intersection method; that is, a manometer differential of zero at which $H = 0$ was not reached, and the two curves of manometer readings versus time did not cross.

Measurements taken in the test pond were performed primarily to become familiar with the field operations and measurement procedures using the ARS meter. The conditions under which the tests were conducted were not ideal and only a limited number of tests were made. These conditions prevent the drawing of conclusions from the comparisons of seepage measurements made with the ARS meter, the Bureau of Reclamation meters and the test pond. However, all tests results are presented. Table 3 contains the average seepage rates indicated by the ARS meter, the Bureau meters, and ponding for days on which concurrent tests were taken. Three Bureau meters were installed at different locations along the length of the section while only one ARS meter was used. To determine the approximate seepage from the natural soil in the pond, it was necessary to correct the overall pond seepage rate for the increased seepage in part of the pond due to the sand trench, Column 8, Table 3. The seepage flow from the sand trench, as determined from measurements with the Bureau meters, was subtracted from the overall pond seepage and the remaining seepage quantity was considered to be acting only on the wetted area of the natural soil outside the sand trench.

There appears to be some agreement between the corrected pond seepage rates and the seepage rates determined with the Bureau meters. The seepage rates determined from one measurement with the ARS meter do not, and are not expected to agree with the rates determined by ponding or with the Bureau meters. An isolated seepage meter measurement in a canal is not likely to be indicative of the average seepage rate from the entire canal or pond. However, a reasonable number of accurate seepage meter measurements at random locations should give an average seepage rate for the entire pond. The number of tests performed with the ARS and Bureau

seepage meters in the pond test section is not sufficient to warrant any conclusion as to the accuracy of either meter. In addition, the computed seepage rates for the undisturbed sections of the test pond are questionable because the seepage from the sand trench could not be accurately measured.

FUTURE INVESTIGATIONS

Additional laboratory studies of the ARS meter in a new 4-foot-diameter steel seepage tank will be conducted to determine the accuracy of seepage measurement in uniform soil under controlled conditions. These laboratory tests will be made prior to any further field tests. The primary reason for conducting the laboratory studies is to determine the validity of the theory as proposed by Bouwer and to establish operating procedures. Further field tests will be conducted to determine the correlation between average seepage rates obtained from the ARS meter and seepage rates obtained by ponding.

CONCLUSIONS

1. Data collected thus far in this study are not sufficient to warrant any conclusions as to the accuracy of the ARS meter in measuring seepage.
2. A limited number of laboratory tests indicate that the ARS meter may measure about 25 percent lower than actual seepage rates.
3. Seepage rates measured successively at one placement with the ARS meter under controlled laboratory conditions in the seepage tank were repeatable.
4. Seepage measurement with the ARS meter using the variable-head technique is somewhat faster than with the Bureau seepage meter.
5. Additional laboratory and field studies are required before the accuracy and reliability of seepage measurements with the ARS meter can be determined.

Table 1

Tests of ARS Seepage Meter in Seepage Tank

Test No.	$I_{s, o}$ Eq (1) cfd*	$I_{s, o}$ Eq (2) cfd*	Tank seepage cfd*
1	5.88	6.43	8.26
2	5.88	6.23	8.26
3	5.51	6.12	8.26
4	6.28	6.43	8.26
5	5.90	6.23	8.26
6	5.97	6.64	8.30
7	6.41	6.54	8.30
8	5.43	5.71	8.30
9	6.34	6.23	8.30
10	6.34	6.64	8.30
11	6.32	6.43	8.30
Average	6.02	6.33	8.28

$$\text{Eq (1)}--I_{s, o} = \frac{(2.3)(1440)H_b R_v^2}{t R_c^2} \log \frac{H_o - H_b}{H_t - H_b}$$

$$\text{Eq (2)}--I_{s, o} = \frac{1440 R_v^2}{R_c^2} \left(\frac{dH}{dt} \right)_{H=0}$$

*cubic feet per square foot per day

Table 2

Tests of ARS Seepage Meter in Test Pond

Date	I _{s, o} Eq (1) cfd	I _{s, o} Eq (2) cfd	Remarks
10-25-62	2.03	1.97	
10-25-62	1.95	2.08	
10-25-62	1.99	1.97	
10-26-62	1.85	2.08	
10-29-62	1.94	2.28	
10-30-62	2.23		Apparent leak in meter
11- 8-62*	0.35		Test too short for Equation (2)
11- 8-62	0.30	0.31	
11- 9-62	0.28	0.42	Curve extrapolated
11-13-62	0.35	0.29	
11-13-62*	0.02		Test too short for Equation (2)
11-13-62	0.05		Test too short for Equation (2)
11-16-62	0.04		Test too short for Equation (2)
11-16-62	0.04		Air bubble in line
11-19-62*	2.32	2.49	
11-19-62	2.13	2.28	
11-20-62	1.83	1.76	
11-21-62	6.01	6.02	
11-21-62	7.19	6.02	
11-21-62	5.90	5.81	
11-23-62	3.39	3.32	
11-26-62	1.58	1.45	
11-28-62	1.74	1.66	
Average	2.51	2.48	17 tests using both equations

$$\text{Eq (1) } I_{s, o} = \frac{(2.3)(1440)H_b R_v^2}{t R_c^2} \log \frac{H_o - H_b}{H_t - H_b}$$

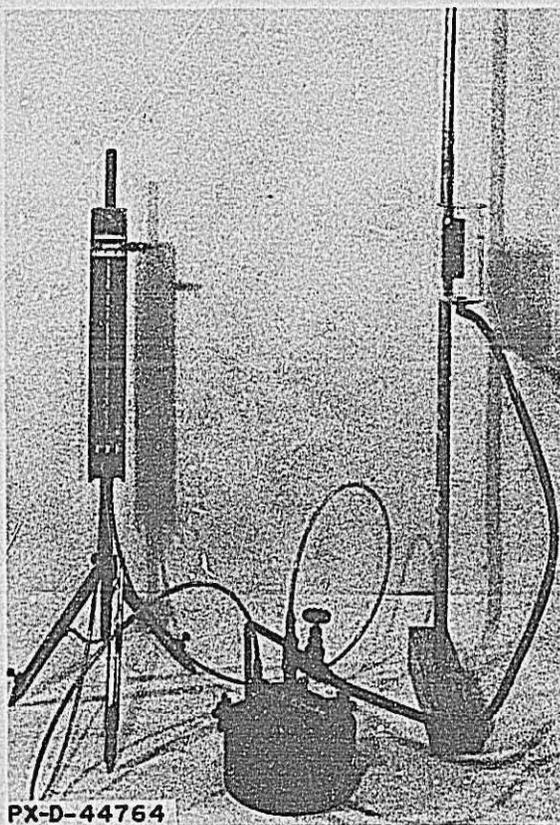
$$\text{Eq (2) } I_{s, o} = \frac{1440 R_v^2}{R_c^2} \left(\frac{dH}{dt} \right)_{H=0}$$

*Meter reset at different location

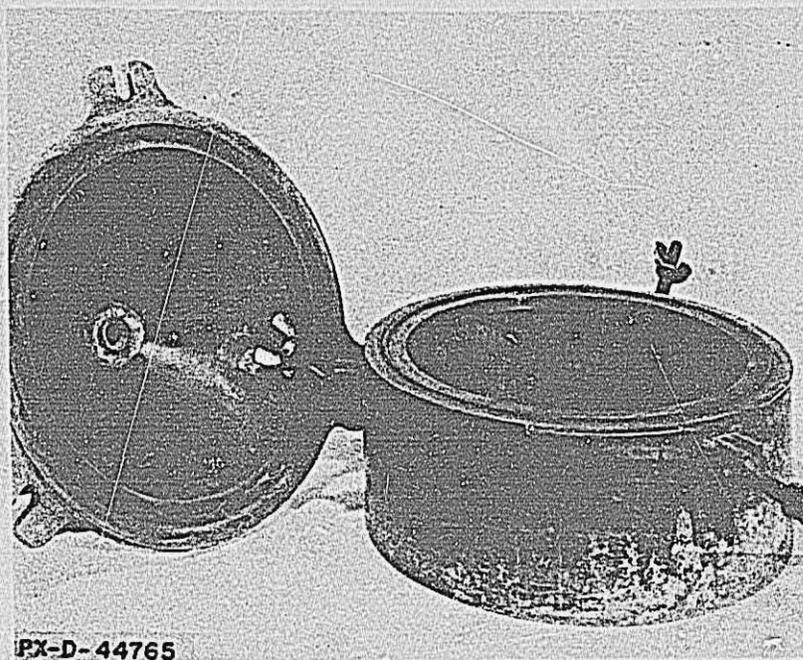
Table 3

Comparison of Seepage Measurements--Test Pond

Test No.	Date	Meter	No. meters	No. measurement	Average seepage cfd	Entire pond average seepage cfd	Pond, corrected for sand trench cfd
1	11- 8-62	ARS	1	2	0.33	3.70	2.05
		Bureau	3	7	1.79		
2	11- 9-62	ARS	1	1	0.35	3.77	1.83
		Bureau	3	7	1.39		
3	11-13-62	ARS	1	3	0.13	3.85	1.46
		Bureau	3	3	1.17		
4	11-14-62	ARS	1	2	0.03	3.94	2.67
		Bureau	3	3	2.36		
5	11-16-62	ARS	1	1	0.04	3.84	2.04
		Bureau	3	3	1.86		
6	11-19-62	ARS	1	2	2.31	3.84	1.51
		Bureau	3	3	1.17		
7	11-20-62	ARS	1	1	1.79	3.79	1.52
		Bureau	3	3	1.21		
8	11-21-62	ARS	1	3	6.16	3.88	1.65
		Bureau	3	3	1.32		
9	11-23-62	ARS	1	1	3.36	3.94	1.59
		Bureau	3	3	1.15		
10	11-26-62	ARS	1	1	1.51	3.85	1.32
		Bureau	3	3	1.24		

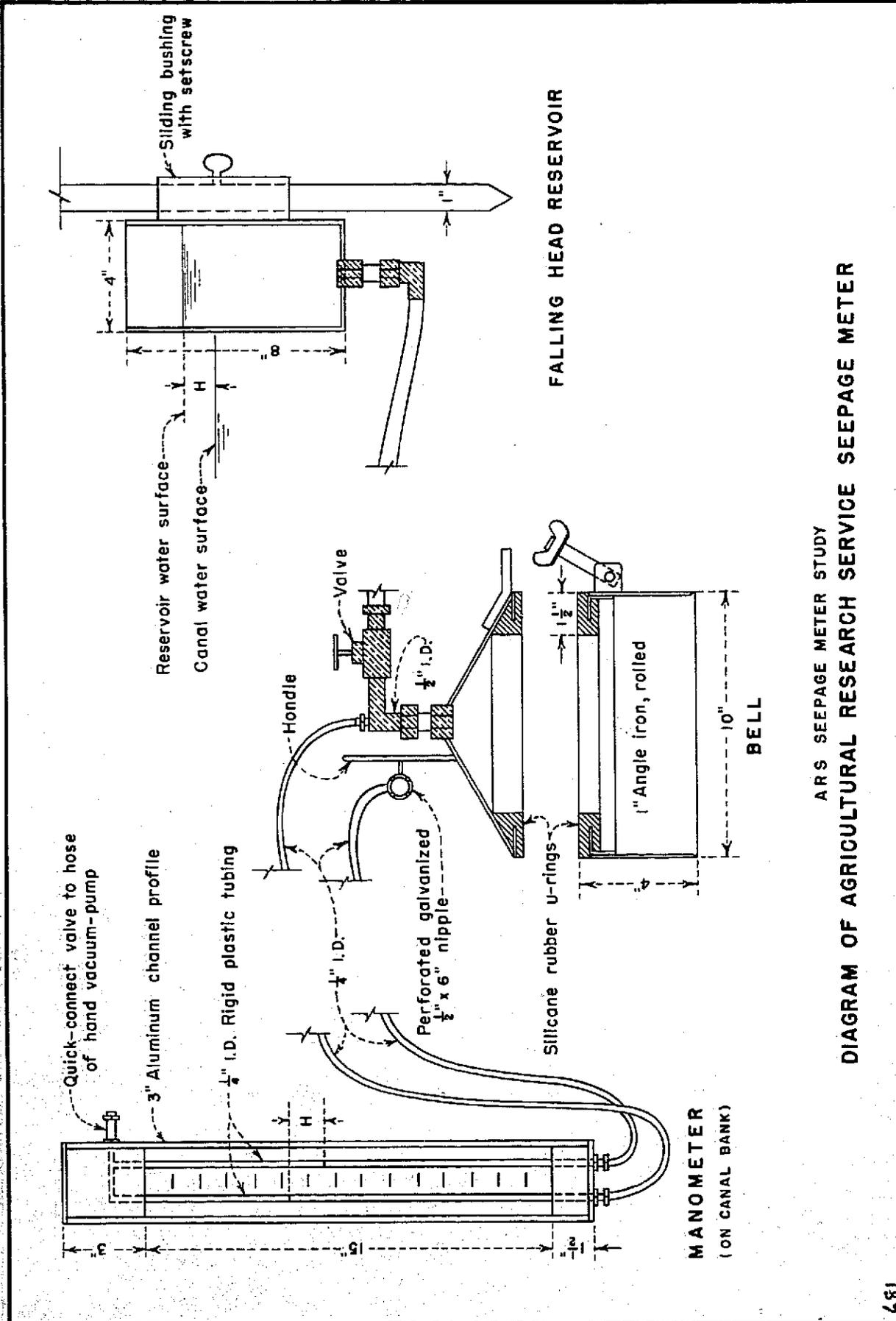


A. Assembled seepage meter.



B. Seepage meter bell and lid with "O" ring seal.

ARS SEEPAGE METER STUDY
SEEPAGE METER USED IN LABORATORY AND FIELD



ARS SEEPAGE METER STUDY
DIAGRAM OF AGRICULTURAL RESEARCH SERVICE SEEPAGE METER

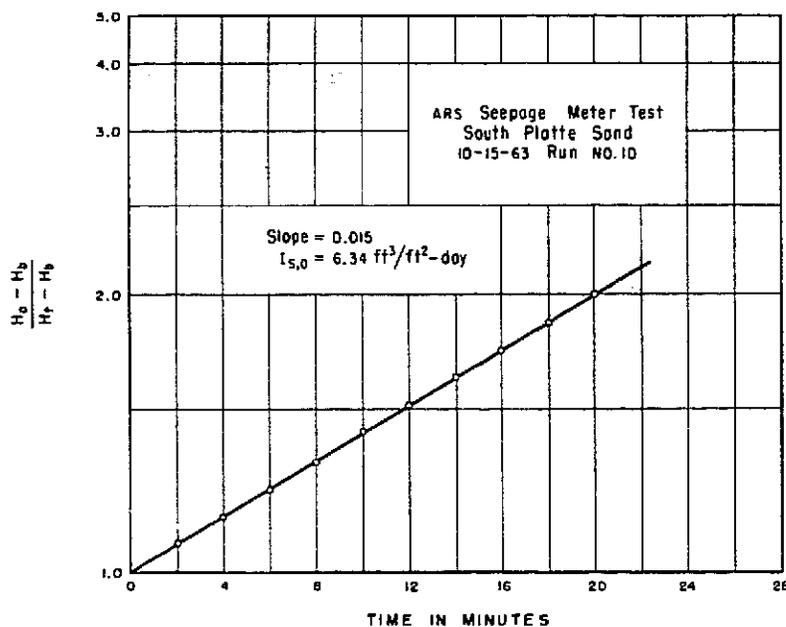


A. Test pond used for seepage meter study
(1) pond inlet control valve float (2) water stage recorder and staff gage.

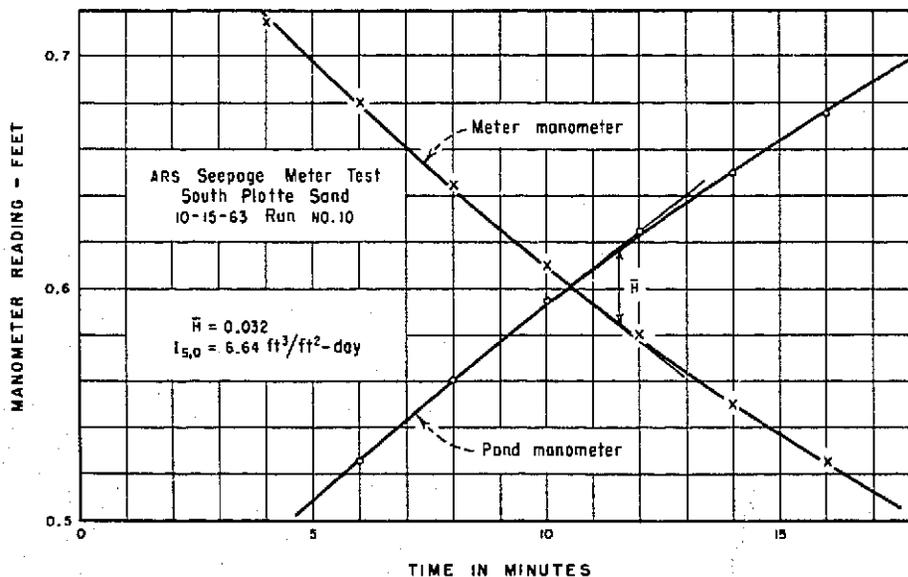


B. ARS seepage meter installation in test pond
(1) seepage meter bell, (2) falling level reservoir, (3) manometer.

ARS SEEPAGE METER INSTALLATION
IN POND TEST SECTION



A. GRAPH FOR SEEPAGE CALCULATION USING LOGARITHMIC EQUATION



B. GRAPH FOR SEEPAGE CALCULATION USING INTERSECTION METHOD

ARS SEEPAGE METER STUDY
SEEPAGE CALCULATION GRAPHS

ABSTRACT

A seepage meter designed by the Agricultural Research Service and the proposed operating procedure were investigated for accuracy and dependability. Laboratory studies in a tank and simulated field tests in a canal-shaped pond were performed to evaluate the meter. The meter, consisting of a 10-inch-diameter bell which is pressed into the earth to isolate the test area, and an adjustable height reservoir to supply water to the test area, is operated on a falling-head principle rather than on the constant-head principle used in the Bureau of Reclamation meter. Seepage measurements made under controlled conditions were found to be repeatable. Simulated field measurements produced apparently satisfactory results, but more data are required before meter accuracy and dependability can be stated.

ABSTRACT

A seepage meter designed by the Agricultural Research Service and the proposed operating procedure were investigated for accuracy and dependability. Laboratory studies in a tank and simulated field tests in a canal-shaped pond were performed to evaluate the meter. The meter, consisting of a 10-inch-diameter bell which is pressed into the earth to isolate the test area, and an adjustable height reservoir to supply water to the test area, is operated on a falling-head principle rather than on the constant-head principle used in the Bureau of Reclamation meter. Seepage measurements made under controlled conditions were found to be repeatable. Simulated field measurements produced apparently satisfactory results, but more data are required before meter accuracy and dependability can be stated.

ABSTRACT

A seepage meter designed by the Agricultural Research Service and the proposed operating procedure were investigated for accuracy and dependability. Laboratory studies in a tank and simulated field tests in a canal-shaped pond were performed to evaluate the meter. The meter, consisting of a 10-inch-diameter bell which is pressed into the earth to isolate the test area, and an adjustable height reservoir to supply water to the test area, is operated on a falling-head principle rather than on the constant-head principle used in the Bureau of Reclamation meter. Seepage measurements made under controlled conditions were found to be repeatable. Simulated field measurements produced apparently satisfactory results, but more data are required before meter accuracy and dependability can be stated.

ABSTRACT

A seepage meter designed by the Agricultural Research Service and the proposed operating procedure were investigated for accuracy and dependability. Laboratory studies in a tank and simulated field tests in a canal-shaped pond were performed to evaluate the meter. The meter, consisting of a 10-inch-diameter bell which is pressed into the earth to isolate the test area, and an adjustable height reservoir to supply water to the test area, is operated on a falling-head principle rather than on the constant-head principle used in the Bureau of Reclamation meter. Seepage measurements made under controlled conditions were found to be repeatable. Simulated field measurements produced apparently satisfactory results, but more data are required before meter accuracy and dependability can be stated.

Hyd-529
Brockway, C. E.
PROGRESS REPORT--INVESTIGATION OF A SEEPAGE METER
DESIGNED BY THE AGRICULTURAL RESEARCH SERVICE, U. S.
DEPARTMENT OF AGRICULTURE
DESCRIPTORS--Seepage/*canal seepage/*seepage losses/meters/
leakage/ponding tests
IDENTIFIERS--Seepage meters/variable head/Bureau of Reclamation/

Hyd-529
Brockway, C. E.
PROGRESS REPORT--INVESTIGATION OF A SEEPAGE METER
DESIGNED BY THE AGRICULTURAL RESEARCH SERVICE, U. S.
DEPARTMENT OF AGRICULTURE
DESCRIPTORS--Seepage/*canal seepage/*seepage losses/meters/
leakage/ponding tests
IDENTIFIERS--Seepage meters/variable head/Bureau of Reclamation/

Hyd-529
Brockway, C. E.
PROGRESS REPORT--INVESTIGATION OF A SEEPAGE METER
DESIGNED BY THE AGRICULTURAL RESEARCH SERVICE, U. S.
DEPARTMENT OF AGRICULTURE
DESCRIPTORS--Seepage/*canal seepage/*seepage losses/meters/
leakage/ponding tests
IDENTIFIERS--Seepage meters/variable head/Bureau of Reclamation/

Hyd-529
Brockway, C. E.
PROGRESS REPORT--INVESTIGATION OF A SEEPAGE METER
DESIGNED BY THE AGRICULTURAL RESEARCH SERVICE, U. S.
DEPARTMENT OF AGRICULTURE
DESCRIPTORS--Seepage/*canal seepage/*seepage losses/meters/
leakage/ponding tests
IDENTIFIERS--Seepage meters/variable head/Bureau of Reclamation/

HYDRAULIC CONVERSION TABLE
British to Metric Units

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
<u>LENGTH</u>		
Inches	25.4 (exactly)	Millimeters
Feet	30.48 (exactly)	Centimeters
Miles	1.609344 (exactly)	Kilometers
<u>AREA</u>		
Square inches	6.4516 (exactly)	Square centimeters
Square feet	0.092903 (exactly)	Square meters
Acres	0.0040469	Square kilometers
Square miles	2.58999	Square kilometers
<u>VOLUME</u>		
Cubic feet	0.0283168	Cubic meters
	28.3168	Liters
Gallons (U. S.)	3.78543	Liters
Cubic yards	0.7646	Cubic meters
Acre feet	1233.5	Cubic meters
<u>MASS</u>		
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Tons (2,000 pounds)	907.185	Kilograms
<u>ACCELERATION</u>		
Feet per second per second	0.3048	Meters per second per second
<u>FORCE/UNIT AREA</u>		
Pounds per square inch	0.070307	Kilograms per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
Feet of water column (at 20° C)	2.246	Centimeters of mercury column
	0.03041	Kilograms per square centimeter
<u>MASS/VOLUME (DENSITY)</u>		
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
<u>VELOCITY</u>		
Feet per second	30.48 (exactly)	Centimeters per second
Inches per hour	2.540 (exactly)	Centimeters per hour
Feet per year	0.3048 (exactly)	Meters per year
<u>FLOW</u>		
Cubic feet per second	0.028317	Cubic meters per second
	28.317	Liters per second
Cubic feet per minute	0.4719	Liters per second
Gallons per minute	0.06309	Liters per second
	3.7854	Liters per minute
<u>POWER</u>		
Horsepower (British) (Defined 550 ft lb/sec)	745.700 1.014	Watts Horsepower (Metric) (Defined 75 kg-m/sec)
<u>SEEPAGE</u>		
Cubic feet per square foot per day	304.8	Liters per square meter per day
<u>VISCOSITY</u>		
Dynamic Viscosity (Pound second per square foot)	4.8824	Kilogram second per square meter
Kinematic Viscosity (Square feet per second)	0.092903 (exactly)	Square meters per second
<u>SURFACE TENSION</u>		
Pounds per foot	1.4882	Kilograms per meter
<u>GAS CONSTANT</u>		
Feet per degree F	0.5486	Meters per degree Celsius*

*For all practical purposes, the Celsius and Centigrade scales are synonymous.