Duplicating has plates on Text and Dwgs.

HYD-257

MASTER FILE COPY
BUREAU OF RECLAMATION
HYDRAULIC LABORATORY
NOT TO BE REMOVED FROM FILES

HYD 257

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

A STUDY OF THE HYDRAULIC CHARACTERISTICS OF CONTROL DEVICES FOR THE UNDERDRAIN SYSTEM OF THE FRIANT-KERN CANAL CENTRAL VALLEY PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd.-257

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

APRIL 18, 1949

CONTENTS

	Page
Purpose of Study	1
Conclusions	1
Recommendations	2
Acknowledgment	3
Introduction	4
Description of Prototype	4
Test Facilities	4
Test Procedure	5
Preliminary Investigation	5
Initial Tests of Flap Valve Control	5
Investigation of Seepage Quantity	6
Flow of Seepage Water to Underdrains	6
Seepage Flow Equation	6
Computation of Seepage Flow	7
Pressure Distribution Under Canal Lining	8
Investigation of Flap Valves	9
Selection of Valve for Alterations	9
Capacity of Unaltered Valve	9
Effect of Flap Counterbalance	10
Effect of Flap Weight	10
Effect of Hinging Flap over Center of Gravity	10
Effect of Seat Width	11
Characteristics of Project Flap Valve	11
Characteristics of All-Brass Flap Valve	12
Characteristics of Rectangular Flap Valve	12
Investigation of Weephole Type Underdrain Control	13
Weephole Underdrain Controls	13
Characteristics of Weephole with Rising Disk	13
Characteristics of Weephole with Rubber Flap	14

APPENDIX 1

Flap Valves for 6-inch Drain Line--Friant-Kern Canal--
Central Valley Project 16

LIST OF FIGURES

Number		Page
1	Location Map	18
2	Concrete Canal Lining Underdrains	19
3A	Electrical Analogy Tray Model	20
3B	Flap Valves	20
4	Curves for Coefficient β	21
5	Capacity Curves for Underdrain Flap Valves	22
6	Capacity Curves for Rectangular Flap Valve	23
7	Capacity Curves for Underdrain Weephole	24

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Research and Geology Division
Denver, Colorado
Date: April 18, 1949

Laboratory Report No. 257
Hydraulic Laboratory
Compiled by: J. C. Schuster
Reviewed by: J. W. Ball

Subject: A study of the hydraulic characteristics of control devices for the underdrain system of the Friant-Kern Canal--Central Valley Project, California.

PURPOSE OF STUDY

The purpose of this study was to determine the adequacy of flap valves for controlling the flow of seepage water from the Friant-Kern canal lining underdrain system, without exceeding the maximum allowable pressure of 0.67 foot of water under the lining. The program was extended to include a study of the hydraulic characteristics of two other types of underdrain control devices.

CONCLUSIONS

1. In any underdrain system, one of the first considerations should be the prevention of the underdrain control becoming inoperative because of corrosion by oxidation or electrolytic action, silting, bonding (such as rubber to metal), or biological growth.

2. The quantity of seepage flow to each drain for any combination of factors of permeability, watertable, length of drainage section, and drain arrangement governing the flow quantity, should not exceed the capacity of the control device for the critical head.

3. The pressure conditions under the lining will be more critical with the canal empty than when it contains enough water to submerge the exits of the underdrains. With no water in the canal and the invert of the flow passage of the exits placed 2 inches above the lining surfaces, the head for producing flow from the underdrains must not be greater than 0.21 of a foot or the buckling pressure of 0.67 of a foot will be exceeded. The allowable head differential will be increased to 0.67 of a foot for the buckling pressure when the exits are submerged.

4. Should a perfect seal occur between the contact surfaces of the valve seat, the head required to open the flap for any appreciable submergence would be considerably larger than the maximum of 0.67 foot used in this study. The effect of this type of sealing was negligible for all valves tested.

5. The flap valves purchased from the Iowa Valve Company, the National Cast Iron Pipe Company, and the Flockhart Valve Company will not operate satisfactorily under the low-pressure differential required in the Friant-Kern installation when che canal is empty.

6. The valve with the 4-pound bronze flap, furnished by the project for testing, will operate satisfactorily provided that the seepage flow into a single drain does not exceed 0.01 cubic foot per second, and that there is no corrosion and a minimum frictional resistance in the hinge. By counterbalancing the flap of this valve, it is possible to make it open under extremely small heads and increase the capacity to 0.06 cubic foot per second for the 0.21-foot head.

7. Assuming no corrosion and a minimum frictional resistance in the hinge, the three heavy commercial valves can be made to open at heads less than 0.21 foot by counterbalancing the flaps, but the discharge capacity for this maximum allowable head will be very small (approximately 0.03 cubic foot per second for the National Cast Iron Pipe Company valve).

8. A "sloppy" fit should be provided in the hinge of any flap valve used in an underdrain system where operation under small heads is required.

9. A lightweight flap (3 pounds or less) with its hinge over the center of gravity could be used to replace the heavy flaps of the valves already installed.

10. A flap valve with a rectangular flow passage and lightweight flap will have better operating characteristics than one with a circular opening having the same area and invert elevation.

11. A weephole through the canal lining, controlled by a rubber flap, is a feasible means of passing seepage flow from beneath the canal. The material of the flap, the weight of the flap, and the position of the hinge point are important design factors.

12. An underdrain control consisting of a lightweight rising disk on a stem and supports, covering a weepholo in the canal lining, might be used in cases whore the water is free of moss, silt, or other iebris.

RECOMMENDATIONS

1. Sufficient field information, including groundwater elevations and type and permeability of soils, be obtained for determining the adequacy of all canal underdrain systems prior to construction.

2. A lightweight flap (3 pounds or less) with its hinge over the center of gravity be used to replace the heavy flaps of the valves already installed in the Friant-Kern Canal, and that additional outlets be provided for the existing long drains, should actual field conditions indicate seepage flow in excess of the capacity of the present installation.

3. A "sloppy" fit be provided in the hinge of any flap valve used in an underdrain system operating under low heads.

4. Should the flap valve be used to control seepage flow from a canal underdrain system, the valve should have a rectangular flow passage and lightweight flap and be installed with the invert of the passage as near the surface of the lining as possible.

5. If the use of a nonmetal flap is contemplated, the sealing characteristics should be investigated before the design is adopted. Information concerning plastic materials is contained in Appendix 1.

6. If the flap-controlled weephole underdrain is considered, a finished flap should be studied in the laboratory before the design is adopted.

ACKNOWLEDGMENT

Engineers from the Canals and Mechanical Divisions and the Earth Materials Laboratory collaborated in the canal underdrain investigations discussed in this report.

INTRODUCTION

Description of Prototype

The Friant-Kern Canal, Central Valley Project, California, (Figure 1) has been designed with a 3-1/2-inch reinforced concrete lining. This lining can withstand a maximum differential water pressure of 0.67 of a foot without buckling. To protect the lining against buckling due to a differential water pressure resulting from a high watertable or rainstorm, 6-inch open-jointed sewer pipe drains have been provided beneath the floor of the canal (Figure 2). At intervals along the course of the canal, the drainpipes pass upward through the bottom lining and are vented by flap valves. Each valve consists of a body connected by a flange to the end of a drain and a flap which is free to swing out from the body seat when internal pressure from the drainpipe acts upon it. The invert of the valve flow passage has been placed approximately 0.46 of a foot above the lower side of the bottom lining in order to facilitate the installation of the valve, and to assure a minimum interference by moss or accumulating silt. For safety of the lining, the flap valve must open and be capable of discharging the drainage flow at heads not greater than 0.21 of a foot when the canal is empty and the invert of the drain is 2 inches above the lining. The differential head should not be greater than 0.67 of a foot when there is sufficient water in the canal to submerge the valve. Since little was known of the operating characteristics of flap valves at small heads, it was requested that several of the commercial designs installed in the Friant-Kern Canal be tested in the laboratory.

Test Facilities

A 20-foot horizontal length of 6-inch standard pipe terminated by a flange inside of a box in which the water depth could be varied was provided to test the gates in the laboratory. Water was supplied by a vertical 8-inch propeller pump and measured by an orifice-venturi meter. A 1-inch standard pipe vent was placed in the 6-inch pipe to facilitate applying pressure to the valve flap. Pressures were measured by a water manometer connected to a piezometer located one pipe diameter upstream from the extreme end of the valve body and in the bottom of the 6-inch pipe. To facilitate obtaining the pressure required to open the valve, a set of electrical contacts completing the circuit to a small light bulb was attached to the flap and body. The slightest movement of the flap would break the contact which would interrupt the current to the bulb and indicate the opening of the valve.

An electric analogy tray was used to determine the amount of seepage flow which might be expected to enter the underdrains. The tray, 1 inch in depth, having sides of strip plastic which represented a half section of the canal having a depth of 16 feet, a bottom width of 18 feet, and a side slope of 1-1/4 to 1, was constructed on a 50- by 50- by 3/8-inch glass plate to a scale of 1/2 inch = 1 foot (Figure 3A). The remaining portion of the tray boundary was formed by placing plastic strips on the vertical centerline below the canal bottom, along a horizontal line 8 inches above the floor and outside of the canal wall, and on an arc of 40-inch radius between these two lines. The center of the 40-inch radius was at the intersection of the canal centerline and the horizontal line 8 inches above the canal floor. An electrode was placed along the curved boundary to represent the maximum potential of the groundwater. Two small electrodes represented one and one-half drain filters of a three-drain system and the minimum potential at the canal bottom. The electrolyte used in the model was tap water approximately 1/2 inch in depth.

Test Procedure

Each flap valve was bolted to the flange inside the box and water introduced slowly into the 6-inch pipe through the 1-inch vent until the flap was forced open by the pressure in the pipe. The head required to open the flap was read from a water manometer at the instant the indicator light signified that the flap started to open. The same procedure was followed whether the valves were submerged or unsubmerged.

Accepted standard procedures were followed in the electric analogy tray tests.

PRELIMINARY INVESTIGATION

Initial Tests of Flap Valve Control

The initial tests on the four valves received from the project indicated that none would be entirely satisfactory for the underdrain system.

The opening heads were excessive for the unsubmerged condition for three of the valves, Table 1, and it was not certain that the capacity of any of the valves was adequate, since the quantity of seepage flow was unknown.

Table 1

Manufacturer	Differential head Submerged	Pressure in feet of water, referred to invert of 6-inch pipe Unsubmerged
Friant Valve No. 13141 (manufacturer unknown)	0.03	0.11
Iowa Valve Company	0.093	0.31
National Cast Iron Pipe Company	0.23	0.48
Flockhart Valve Company No. 5149	0.34	0.47

Note: A check of the reliability of the values given above was made by computation using balanced moments about the hinge point, one for the weight of the flap and one for the force produced by the water pressure. Good agreement was obtained.

The investigation resolved into three parts: (1) to determine what quantity of seepage flow might be expected to enter the drains; (2) to determine if the valves had sufficient capacity within the required head range; and (3) to determine if the installed valves could be made to operate satisfactorily by making minor alterations. The program was continued on the basis of these three problems.

INVESTIGATION OF SEEPAGE QUANTITY

Flow of Seepage Water to Underdrains

The capacity of the Friant-Kern Canal underdrain system was limited by the elevation of the drainpipe exits and the resistance of the flap valves; therefore, it was very important to determine the quantity of seepage flow to be expected to enter the underdrains. Electric analogy tests were made for that purpose.

Seepage Flow Equation

The equation, $Q = KHL^{\beta}$, may be used to compute the seepage flow to the canal underdrains, providing all its factors can be evaluated. In the equation

Q = volume per unit time (cubic feet per year)

K = percolation rate (feet per year)

H = height of watertable in feet above drain filter

L = length of canal section in feet, measured along the longitudinal centerline

β = shape factor, dependent upon design and foundation conditions

The factor, β , cannot be determined from physical measurements of an installation but can be obtained through electric analogy studies which consider the flow of current in a conductor analogous to flow of water through granular material (Ohm's Law and Darcy's Law for seepage flow).1/ In the case of the electrical analogy tray, β is the ratio of the resistance of a square unit of the model to the resistance of the model (both containing the same depth of electrolyte).

Two conditions had to be considered in determining the value of β : (1) the effect of changing the depth to an impervious layer; and (2) the effect of changing the height of the watertable above the underdrain filter. Curves were plotted showing the variation in β for the two above conditions (Figure 4). The maximum value obtained was 0.77 for the one-half section of the canal which assumed pervious material of infinite dimensions and a watertable coincident with the top of the canal. A flow net constructed by using data from the electric analogy tray indicated that the discharge would be distributed so that approximately one-fifth of the seepage water flowing to the canal underdrain system would enter the center drain while two-fifths would enter each of the two outside drains.

Computation of Seepage Flow

By using the flow distribution ratio and appropriate values of β , it is possible to compute the seepage flow into any system of underdrains which is geometrically similar to the one tested, if the watertable, length of drainage section, and percolation rate are known. All of these data are not available for specific sections of the Friant-Kern Canal; thus it is not possible at this time to predict the discharge quantities for the underdrain systems of that structure.

1/ E. W. Lane, "Model Studies of the Imperial Dam Desilting Works and Structures in All-American Canal," Hydraulic Laboratory Report No. Hyd 199, p. 93, Bureau of Reclamation, Denver, Colorado, May 1, 1946.

J. N. Bradley, J. B. Drisko, and D. J. Hebert, Preliminary Report No. 2, TM 471, "Hydraulic and Electrical Analogy Model Studies of the Proposed Imperial Dam and Appurtenant Works--All-American Canal Project," Bureau of Reclamation, Denver, Colorado, July 15, 1935.

The amount of seepage for a one-half section of the canal computed from probable maximum values of β, H, K, and L, which might occur along the course of the canal, is 0.80 cubic foot per second. The values of β, H, K, and L used in computing this quantity are as follows:

β = 0.77 maximum value from electric analogy tray tests (figure 4)

K = 4,125 feet per year, Table 2, Earth Materials Laboratory Report No. EM-78, October 12, 1945

H = 16-foot depth of canal or assuming watertable coincident with top of canal

L = 500 feet, Sec. AA, Figure 2

It seems very improbable that the above values would ever exist at one location. If such conditions do exist, the most logical solution would be to decrease the drain length L. The height of the drain exits, being 0.46 foot above the bottom of the lining, limits the head for producing flow to 0.21 foot for the unsubmerged drain exit; thus the maximum length of drain can be determined if the capacity of the drain under this head is known. The capacity must include the influence of any restriction, such as flap gates or other controls, placed at the exit of the drain. The discharge for an open unsubmerged drain under this head is 0.096 cubic foot per second, or about 15 percent of the maximum possible flow; thus, the pressure head for the maximum values will be excessive, even for the unrestricted drain unless the length is limited to about 65 feet or the permeability coefficient does not exceed 490 feet per year.

It must be pointed out that the values of β determined in this study are applicable only to canal cross-sections geometrically similar to that tested and that these values are for a one-half section of the canal. Additional tests would be required to determine β values for other cross-sections and underdrain arrangements.

Pressure Distribution Under Canal Lining

A determination of the pressure distribution on the lining, that is the effectiveness of the drains for reducing pressures throughout the underside of the lining, was not made because of limitations imposed by the temporary electrical analogy equipment used in this study. It was believed that if pressure at any point under the lining exceeded the buckling pressure, the lining would raise slightly from the surrounding soil to form a free water path between the point in question and the underdrain filter, thereby relieving the excessive pressure. There probably will be some silt carried into this path by the seepage flow and so the number of pressure-relieving cycles without damage to the lining may be limited. A detailed pressure-distribution study could be made if the need should ever arise in the design of underdrain systems.

INVESTIGATION OF FLAP VALVES

Selection of Valve for Alterations

It became evident during the preceding tests, that nothing could be gained by using a valve with a greater capacity than an unobstructed drainpipe; therefore, this criterion was used for determining the adequacy of all valves tested. With a determination of approximate seepage flow quantities, it became necessary to find if any of the valves had sufficient capacity to discharge this flow within the required head range, and to find if the installed valves could be made to operate satisfactorily by minor alteration of their parts. Since all of the valves were of similar design (Figure 3B) and had similar hydraulic characteristics, the National Cast Iron Pipe Company valve was studied for the effects of the various alterations. This valve was chosen because it required a greater head to open than any of the other valves when discharging unsubmerged, and any solution obtained from the tests on it would be applicable to the other valves.

Capacity of Unaltered Valve

A head-discharge curve for complete submergence was obtained for the National Cast Iron Pipe Company flap valve (Curve a, Figure 5A). It was found that the differential head required to maintain flow was independent of the depth of tailwater, and that the capacity of the valve for submerged flow was adequate for passing the seepage water.

The head-discharge relationship for the unsubmerged valve was obtained also (Curve a, Figure 5B). The heads to open the valve and maintain flow were excessive. A discontinuity existed in the curve at approximately 0.2 of a second-foot, which was believed caused by a change in the flow conditions in the passage formed between the body seat and flap.

It was believed that the discontinuity resulted from the contraction at the inner periphery of the body seat and the flow conditions in the expanding passage between the seat and flap. The decrease in pressure in the flow passage accompanied the contraction and expansion and created a hydraulic pull force which tended to close the flap, thus increasing the head required to maintain flow. This flow condition existed until the outward movement of the gate by the force of the water changed the dimensions of the passage so that the jet became aerated. When aeration occurred the flap moved out and the depth of water in the pipe decreased.

Effect of Flap Counterbalance

The first alteration made to the National Cast Iron Pipe Company flap valve was the addition of a 5.05-pound counterweight suspended inside the pipe on the upstream side of flap (Figure 5A). The flap was balanced in air by the counterweight so that it might touch the seat or remain slightly open depending upon the action in the hinge. In this condition of balance, the valve starts opening at practically zero head. The discontinuity in the discharge curve was not discernible, probably due to the fact that the balancing of the flap permitted it to be forced open beyond the critical point by a very low head and permitted the jet to aerate at a very small discharge. The discharge was approximately 0.03 of a second-foot when the head in the pipe reached the maximum allowable of 0.21 of a foot (0.67-foot water on bottom of lining) (Curve b, Figure 5B). Calibration for the submerged condition showed the capacity to be satisfactory, 0.27 cubic foot per second for a differential head of 0.010 foot (Curve b, Figure 5A).

Effect of Flap Weight

An 8- by 8- by 1/8-inch brass flap with the same hinge point was made for the National Cast Iron Pipe Company valve (Figure 5C). This flap weighed 2.59 pounds compared to the 10.60 pounds of the original. A discontinuity in the discharge curve similar to that observed for the original flap was still apparent, but occurred at a lower head and a discharge of approximately 0.04 of a second-foot (Curve a, Figure 5C). At a discharge of approximately 0.25 of a second-foot and a head of 0.81 foot, the flap ceased to affect the head at the piezometer and the discharge curve coincided with that for free flow from the pipe. This alteration was not a solution because the head to open the valve and maintain flow was excessive when the valve was not submerged.

Effect of Hinging Flap over Center of Gravity

The 8- by 8- by 1/8-inch brass flap was altered to move the hinge point over its center of gravity (Figure 5C). This change reduced the head required to maintain a given discharge such that the discharge for the 0.21-foot head was approximately 0.10 cubic foot per second, the same as for an unrestricted drain (Curve b, Figure 5C). However, a discontinuity still occurred in the discharge curve and the maximum head under the lining, at the discontinuity, was 0.62 of a foot, which was only slightly less than the maximum allowable. It was desirable to either reduce the head at the discontinuity or eliminate the discontinuity, so further tests were made.

Effect of Seat Width

It was reasoned that the discontinuity caused by the flow condition occurring between the body seat and flap could be eliminated by reducing the width of the seat. The reduction was made by machining the original seat of the National Cast Iron Pipe Company valve to an annular ring 1/8 inch wide by 1/4 inch deep having an inside diameter of 7.12 inches (Figure 5B). The pressure-discharge relationship for the original flap with the altered seat ring is shown by Curve c, Figure 5B. The discontinuity in the discharge curve was eliminated, but the opening head was decreased only slightly. This slight decrease was attributed to the fact that the water pressure acts over a larger area on the inside of the flap.

Data obtained for the 8- by 8- by 1/8-inch brass flap having the same hinge point as the original flap, but with an altered body seat, are shown by Curve c, Figure 5C. There was no discontinuity in the discharge curve but the head to open and maintain flow against the moment of the gate about the hinge point was still too large. With the hinge point moved forward, the head-discharge relationship was the same as for free discharge from an open drain (Curve d, Figure 5C). It is believed that any of the four valves listed in Table 1 could be made to operate satisfactorily by reducing the seat width and providing a lightweight flap hinged over its center of gravity. From these tests, it was concluded also that the most satisfactory flap valve for the underdrain system would be one which has a narrow seat and a lightweight flap with the hinge placed over or near its center of gravity.

Characteristics of Project Flap Valve

Although the heads to open the flap valve with cast-steel body and 4-pound bronze flap received from the project and identified by the number, 13141, were within the specified limits for the submerged and unsubmerged conditions, the discharge capacity was very small for the unsubmerged condition and there was a small discontinuity in the discharge curve at about 0.04 cubic foot per second (Curve a, Figure 5D). Tests were made to determine if the capacity could be increased sufficiently by minor alterations to permit the use of the valve in the Friant-Kern Canal underdrain system. The alterations consisted of: (1) counterbalancing of the bronze flap (Figure 5D), and (2) decreasing the width of the seat by machining the inner periphery of the flap seat ring (Figure 5D).

The capacity of the valve was increased by counterbalancing the bronze flap with a piece of 3/8-inch-diameter brass rod 10-1/2 inches long. The increase in capacity for the submerged valve was substantial while that for the unsubmerged condition was small (about 0.05 cubic foot per second) (Curve b, Figure 5D). The head required to open the valve was negligible for both cases.

The capacity of the valve was not increased materially by the machining of the inner periphery of the flap seat (Curve c, Figure 5D), but the discontinuity in the discharge curve for unsubmerged flow was practically eliminated.

The water from the reservoir at Friant Dam is considered to have a salt content great enough to produce an electrolytic action between the cast-steel body and bronze flap of this valve. This action would make the life of this valve questionable, if the valve were to remain submerged for long periods.

The loose fit in the hinge of this valve will lessen any possibility of its becoming inoperable due to corrosion.

Characteristics of All-brass Flap Valve

An all-brass flap valve, having a body of 6-inch-inside-diameter by 1/4 inch wall brass pipe and a circular flap of 1/8-inch brass plate with the hinge placed vertically above the center of gravity, was constructed and tested (Valve e, Figure 3B). Its design was based upon the results of the tests completed thus far on the four flap valves received from the project. No discontinuity was observed in the discharge curve which, for all practical purposes, coincided with that for an unobstructed drain (Curve e, Figure 5C). This valve was considered entirely satisfactory so far as hydraulic characteristics were concerned. It does have the disadvantage in that cast iron is anodic to brass.

Characteristics of Rectangular Flap Valve

Since it was found that most flap valves are unsatisfactory for installation in low-pressure underdrain systems, a valve for replacing those already installed in the Friant-Kern Canal was proposed by the Mechanical Design Section (Figure 6). This flap valve included a cast-iron adapter flange that lowered the valve flow passage invert 1-1/4 inches below the invert of the underdrain exit, and a 1/8-inch rectangular bronze flap and hinge weighing approximately 1.5 pounds. The seat on the body of this valve was a rectangle with inside dimensions 3-1/4 inches high by 7 inches wide, and a seat width of 9/32 inch. A clearance of 1/16 inch between the hinge pin and bearing was provided to minimize the possibility of corrosion freezing the hinge. The rectangular exit of this valve provided a greater area in contact with the water for small heads, thus for a given depth of water, the opening force is larger than for the circular exit.

The opening head for the unsubmerged rectangular flap valve was 0.06 of a foot of water. Since the invert of the water passage of the valve body was about 0.10 foot below the invert of the drainpipe exit, the opening head for the flap did not affect the depth in the drain (Figure 6).

The rating curves based on the total head on the drain exit and on the total head in the valve body, show that the capacity for this arrangement is essentially the same as an unobstructed drain (Curve a, Figure 6). The capacity of an unsubmerged Friant-Kern Canal underdrain, using this flap valve arrangement, will therefore be limited by the elevation of the drain exit rather than the resistance of the flap valve. The critical heads and corresponding capacities for three drain-exit elevations are shown on Figure 6. The maximum capacity for the drain exits placed 2, 3, and 4 inches above the canal floor are 0.094, 0.036, and 0.004 cubic foot per second, respectively. This valve, as constructed in the laboratory, exhibited good sealing qualities in preventing a reverse flow of water into the underdrain. The only disadvantage was the possibility of corrosion resulting from the use of two dissimilar metals.

INVESTIGATION OF WEEPHOLE TYPE UNDERDRAIN CONTROL

Weephole Underdrain Controls

A weephole type of underdrain was investigated because of the unfavorable opening heads and operating characteristics noted for many of the flap valves in the tests discussed previously in this report. The advantages of this type of underdrain, over that planned for the Friant-Kern Canal, were: (1) that its exit was at a low elevation with respect to the floor of the canal, permitting utilization of more of the maximum allowable underlining pressure for producing flow from the drains, and (2) possible elimination of drain tile. Two devices for controlling the flow from the weephole were tested: (1) a rising rubber disk and (2) a rubber flap (Figure 7).

Characteristics of Weephole with Rising Disk

A rising-disk control for the weephole, tested in the laboratory, consisted of a rubber disk seal; a circular metal plate on top of the rubber disk to prevent its being pushed into the weephole by water pressure from the canal; a guide stem; and a guide bearing with clips to facilitate the removal of the device for inspection (Figure 7A). This control was placed in a 2-inch plastic tube which represented the weephole.

The opening head for the disk was recorded as that which produced an evident flow and not that which caused slight leakage from beneath the disk. This head was recorded by a piezometer installed in the 6-inch conduit supplying the water to the underside of the disk. Water was introduced into the supply conduit slowly and the piezometer reading taken when the disk opened. Since the head required to open this device was somewhat dependent upon the weight of its moving parts, tests were made with various weights placed on top of the disk.

The opening head for the submerged condition appeared to be constant at about 0.03 of a foot for moving parts weighing from 0.11 to 0.65 of a pound, while that for the unsubmerged condition varied from 0.02 to 0.22 of a foot. The fact that the opening head for the submerged condition appeared to remain constant was attributed to the difficulty of determining when the opening actually occurred.

The capacities of the unsubmerged weephole underdrain for weights of 0.11, 0.23, and 0.65 of a pound were approximately 0.01, 0.03, and 0.05 of a cubic foot per second for the maximum allowable lining pressure. The three separate curves at the left of Figure 7C show the effect of the weight of the moving parts upon the head required to produce a given discharge, while the single curve at the right into which the three merge shows the effect of the disk reaching its maximum rise. The high points in the curves are caused by flow conditions between the seating surface of the rubber disk and the lining surface, similar to that described for the flap valve under section "Capacity of Unaltered Valve" of this report. The capacity of the unsubmerged rising disk control, with moving parts weighing up to 0.2 of a pound, would be half that for an uncontrolled 6-inch underdrain of the type placed in the Friant-Kern Canal.

The pattern of the capacity curves for the submerged weephole and three different weights of the moving parts was similar to that for the unsubmerged condition (Figure 7D). However, the head to produce flow remained substantially below the maximum allowable until after the disk reached its maximum rise and the curves merged, thus giving the same maximum capacity of 0.067 of a cubic foot per second for the three weights. The weight of the moving parts is not so critical when the weephole is submerged. The possibility of increasing the capacity of this device by increasing the rise or the size of the weephole was not investigated.

The disadvantages of this control were that moss streamers might entangle the disk when it is in the raised position releasing seepage flow during the time that the canal carries water, and that it was on the floor of the canal where sediment could interfere with its operation. A protective hood could be added but no tests were made to determine its feasibility.

Characteristics of Weephole with Rubber Flap

A second device considered for controlling the flow through a weephole was a rubber flap bolted to the canal lining (Figure 7B). A metal reinforcing disk was placed on top of the 1/8-inch rubber flap to prevent its being pushed into the tube which represented the weephole. The head to open this rubber flap was determined in the same manner as that for the rising disk and it was found to be negligible (Figure 7E). Discharge curves for the submerged and unsubmerged condition were obtained for flaps with hinge distances of 2 and 3 inches and reinforcing disks weighing 0.04, 0.13, and 0.31 of a pound. The weight of the portion of the rubber flaps affecting the operating heads was 0.07 and 0.09 of a pound for the 2- and 3-inch hinge distances.

There were discontinuities in the curves similar to those observed for small openings in the initial flap gate study. It was believed that a reduction in pressure occurred between the rubber flap and lining as the water passed from the tube, thus increasing the head required to force water through the weephole. This reduction in pressure continued until the force of the water lifted the flap and changed the flowlines. The discontinuity of flow is reflected in the discharge curves for both the submerged and unsubmerged weephole.

The maximum capacity at the allowable underlining pressure obtained for this type of control was 0.06 of a cubic foot per second for the unsubmerged condition and 0.12 of a cubic foot per second for the submerged condition.

The head-discharge relationship of the rubber flap might follow two paths, depending upon whether the seepage flow from the weephole is decreasing or increasing. In either case, the head might become sufficient to endanger a 3-1/2-inch-thick lining, unless the hinge distance and weight of the flap are properly designed. The flap should be lightweight and the hinge distance made small enough to eliminate objectionable head rises in the region of discontinuity. Further improvement might be realized by using other hinge and seal designs.

APPENDIX 1

J. K. Richardson   March 8, 1949
Through W. T. Moran and R. F. Blanks

J. L. Gilliland

Flap valves for 6-inch drain lines--Friant-Kern Canal--Central Valley Project.

1. During December 1948, we had several discussions on the question of a suitable material for fabricating the flaps of the drain valves on the Friant-Kern Canal. At that time, I suggested that certain plastics appeared to have the desired properties and should be given consideration.

2. King Plastics and Ingerwerson Manufacturing Company, both of whom are local plastics fabricators, were consulted. Both concerns expressed the belief that certain plastics were suitable for this purpose. Particularly, polyethylene, polystyrene, and saran were proposed. However, since these fabricators were not completely familiar with the long-time behavior of these materials, it was considered advisable to write the manufacturers for their recommendations.

3. After a considerable delay, we have now received replies to our three letters of inquiry. Although the original problem has been eliminated by a change in design, this memorandum has been prepared to summarize the manufacturer's recommendation in the event a similar problem arises.

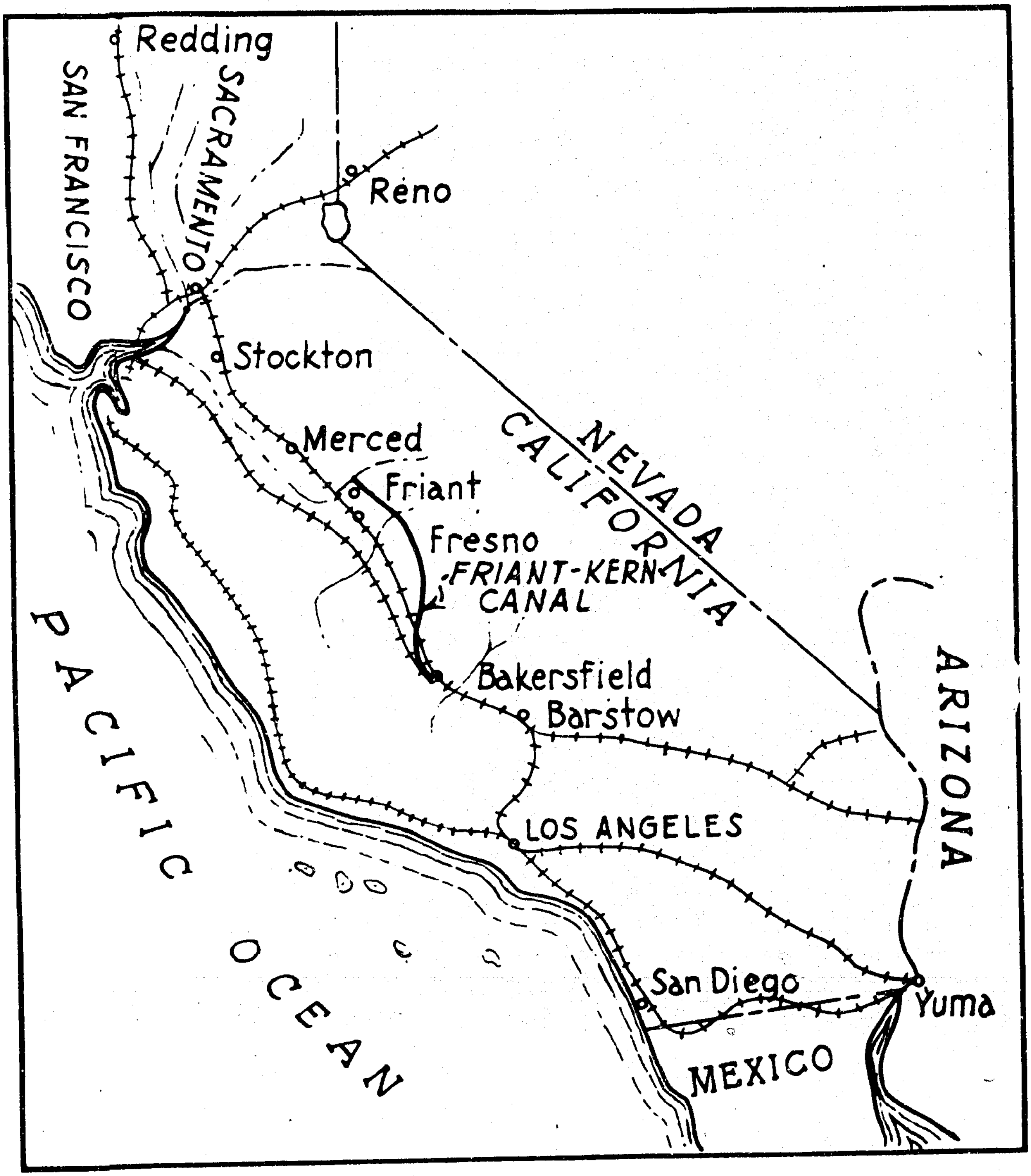
4. Monsanto Chemical Company says flatly that they would recommend no plastic material where the flaps will not be available for examination or replacement for a period of years. They fear also, that plastics have not sufficient impact strength.

5. Dow Chemical Company suggests that either saran or polystyrene might be used if the impact conditions are not too severe. However, they lack aging information, and can only suggest that we answer this question by trial.

6. DuPont is somewhat doubtful of the aging characteristics of polyethylene, as well as the possibility of cold flow distorting the valves.

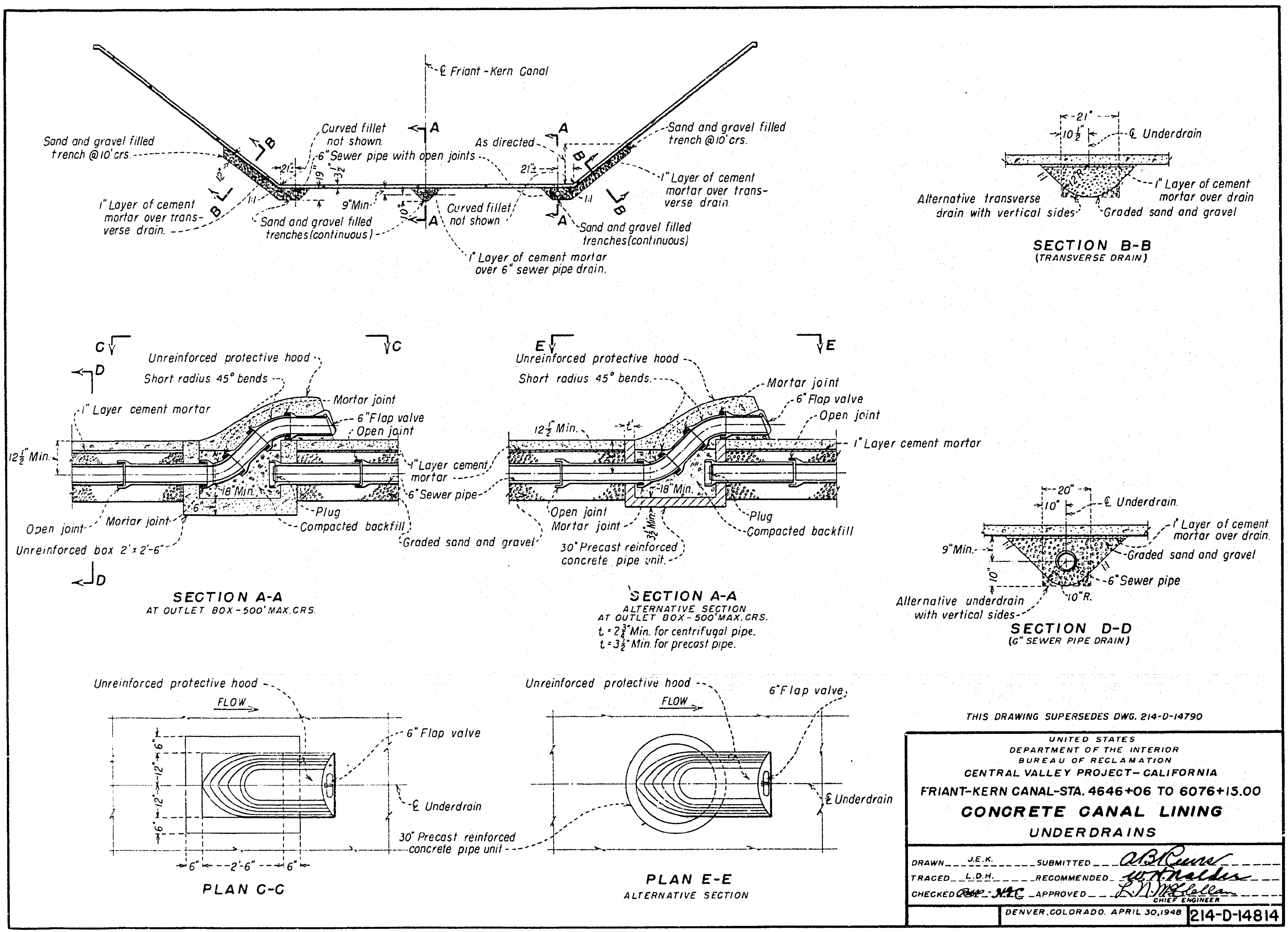
7. In view of these opinions, I have now concluded that we have not sufficient data at this time on the aging characteristics of these materials to warrant a field installation on a very large scale. There is no proof that the materials would not be suitable, and I would not hesitate to chance one of these materials if we had no alternate. However, until the manufacturers gain more experience, there is no advantage in our pressing for an installation at this time.

References: Letter of December 31, 1948, from Monsanto Chemical Company (04881 January 10, 1949)
Letter of January 5, 1949, from Dow Chemical Company
Letter of February 15, 1949, from DuPont and Company (10013 February 18, 1949)

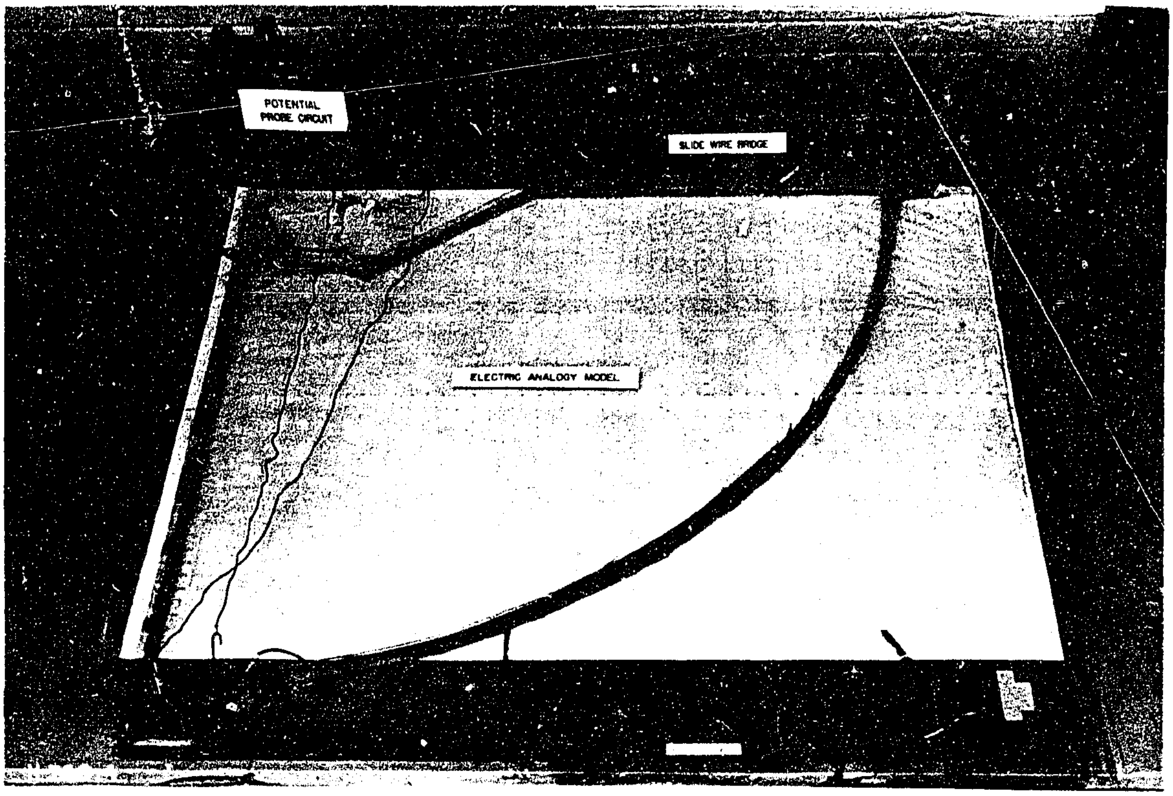


LOCATION MAP
FRIANT-KERN CANAL

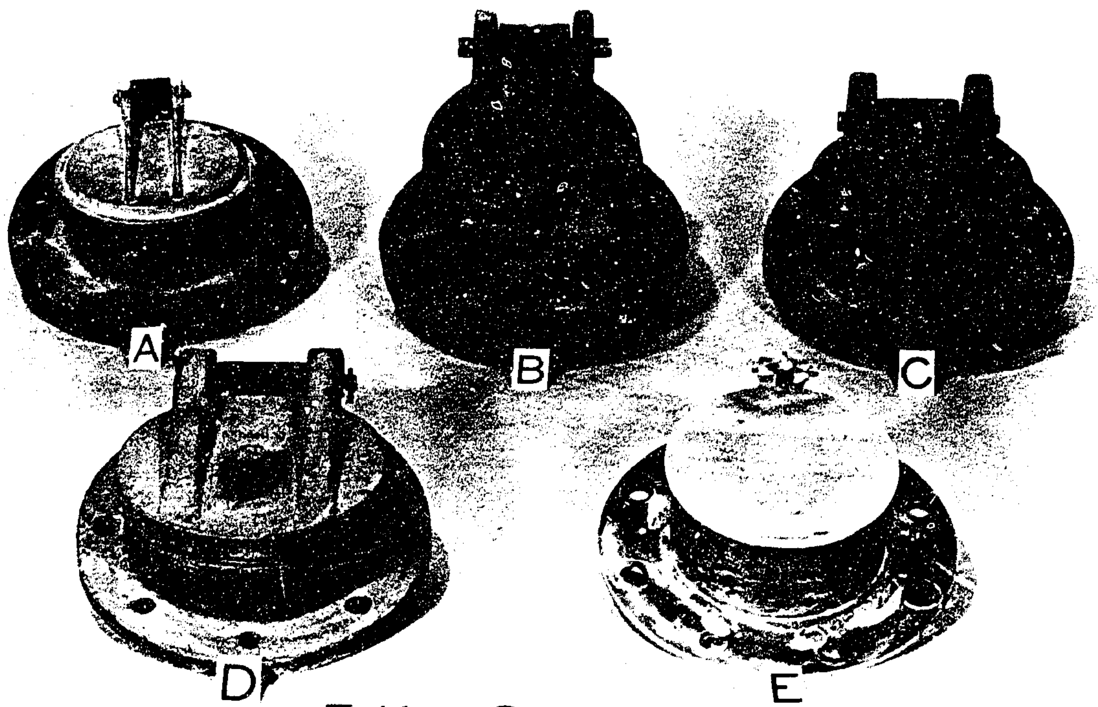
FIGURE 2



℄ Friant - Kern Canal
Sand and gravel filled trench @ 10' crs.
Curved fillet not shown.
6" Sewer pipe with open joints
As directed
Sand and gravel filled trench @ 10' crs.
1" Layer of cement mortar over transverse drain.
9" Min.
Sand and gravel filled trenches (continuous)
Curved fillet not shown
1" Layer of cement mortar over transverse drain.
Sand and gravel filled trenches (continuous)
1" Layer of cement mortar over 6" sewer pipe drain.
21"
10½"
℄ Underdrain
1" Layer of cement mortar over drain
Alternative transverse drain with vertical sides
Graded sand and gravel
SECTION B-B
(TRANSVERSE DRAIN)
Unreinforced protective hood
Short radius 45° bends
Mortar joint
6" Flap valve
Open joint
1" Layer cement mortar
12½" Min.
1" Layer cement mortar
6" Sewer pipe
18" Min.
Plug
Compacted backfill
Graded sand and gravel
Open joint
Mortar joint
Unreinforced box 2' x 2'-6"
SECTION A-A
AT OUTLET BOX - 500' MAX. CRS.
Unreinforced protective hood
Short radius 45° bends.
Mortar joint
6" Flap valve
Open joint
1" Layer cement mortar
12½" Min.
Open joint
Mortar joint
18" Min.
Plug
Compacted backfill
30" Precast reinforced concrete pipe unit
SECTION A-A
ALTERNATIVE SECTION
AT OUTLET BOX - 500' MAX. CRS.
t = 2¾" Min. for centrifugal pipe.
t = 3½" Min. for precast pipe.
20"
10"
℄ Underdrain.
1" Layer of cement mortar over drain.
9" Min.
Graded sand and gravel
6" Sewer pipe
10" R.
Alternative underdrain with vertical sides
SECTION D-D
(6" SEWER PIPE DRAIN)
Unreinforced protective hood
FLOW
6" Flap valve
℄ Underdrain
30" Precast reinforced concrete pipe unit
6" 2'-6" 6"
PLAN C-C
Unreinforced protective hood
FLOW
6" Flap valve
℄ Underdrain
PLAN E-E
ALTERNATIVE SECTION
THIS DRAWING SUPERSEDES DWG. 214-D-14790
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
FRIANT-KERN CANAL - STA. 4646+06 TO 6076+15.00
CONCRETE CANAL LINING
UNDERDRAINS
DRAWN J.E.K. SUBMITTED
TRACED L.D.H. RECOMMENDED
CHECKED APPROVED
CHIEF ENGINEER
DENVER, COLORADO. APRIL 30, 1948
214-D-14814

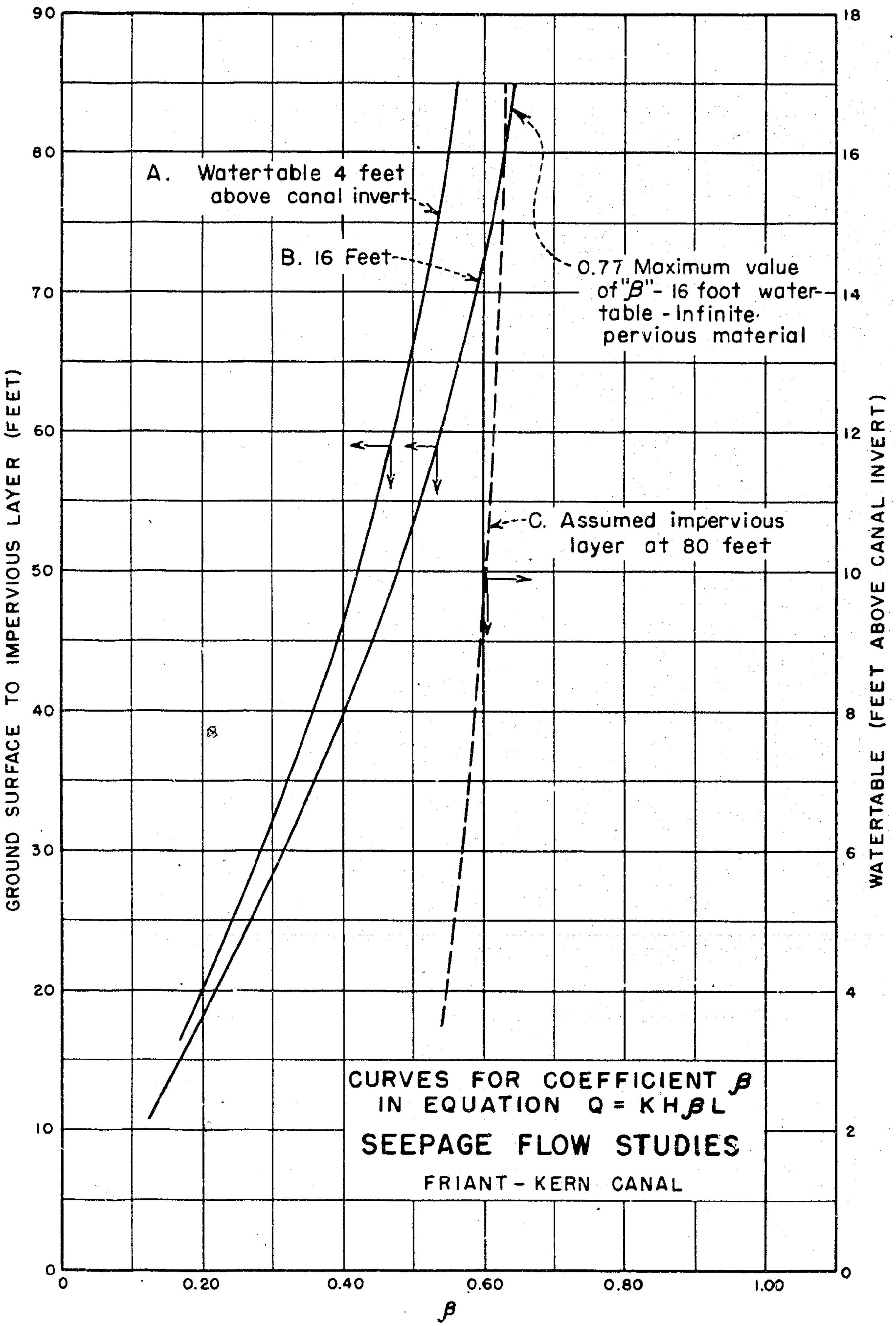


A. Electric Analogy Tray Model



B. a. Friant Valve b. Iowa Valve c. National Cast Iron Pipe Valve d. Flockhart Valve e. All Brass Valve
FRIANT-KERN CANAL

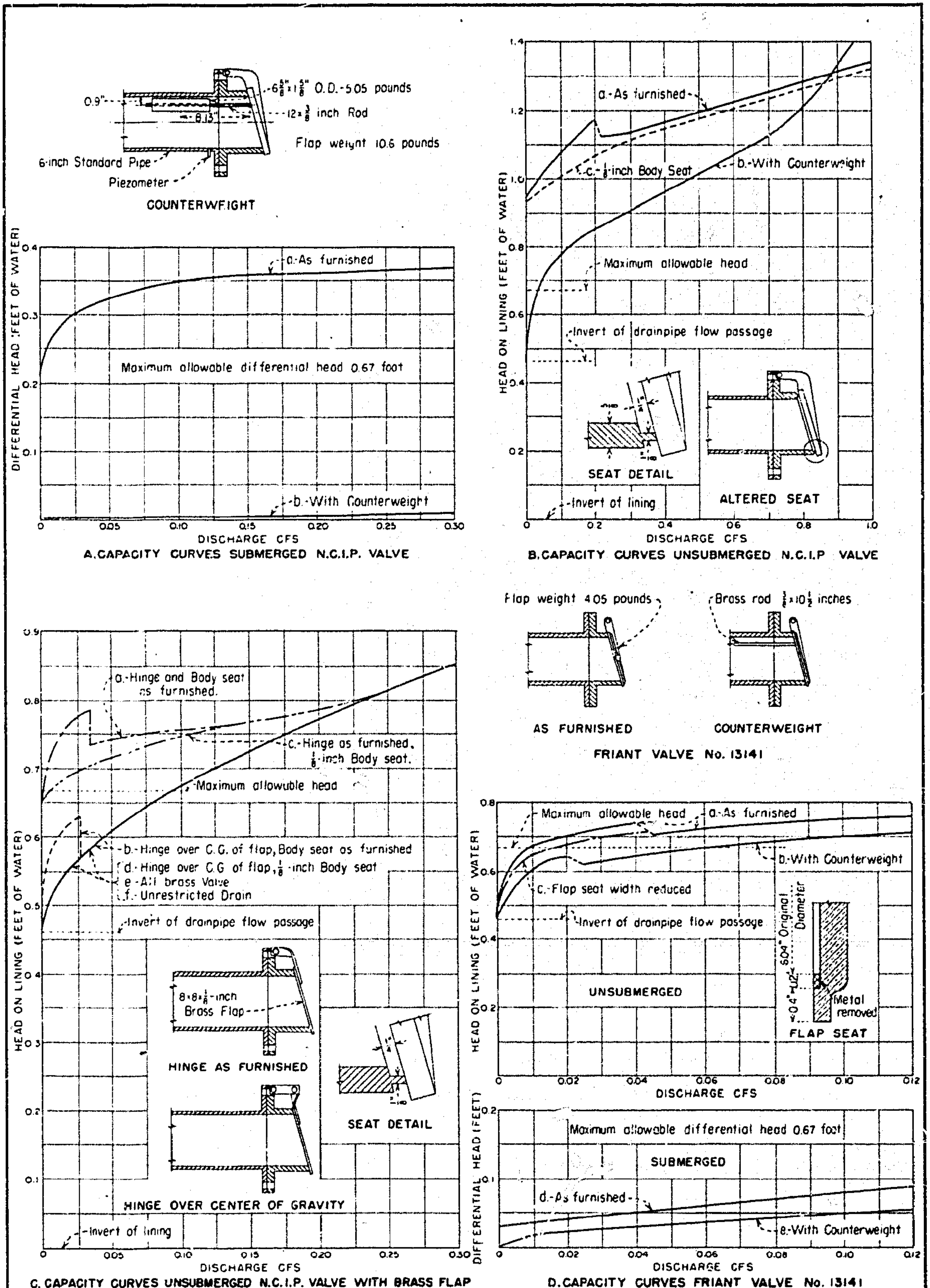
FIGURE 4



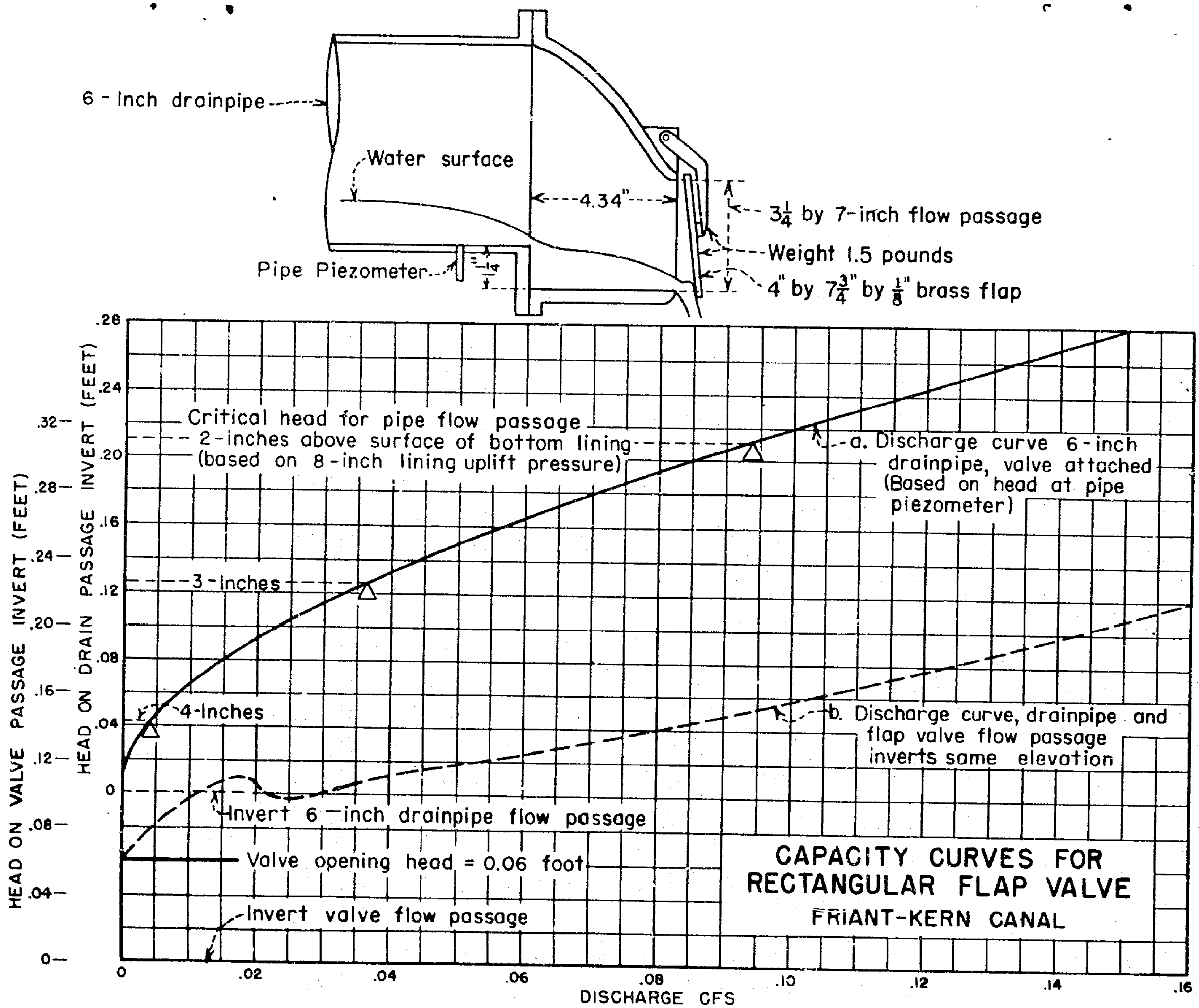
CURVES FOR COEFFICIENT β IN EQUATION $Q = KH\beta L$

SEEPAGE FLOW STUDIES

FRIANT - KERN CANAL



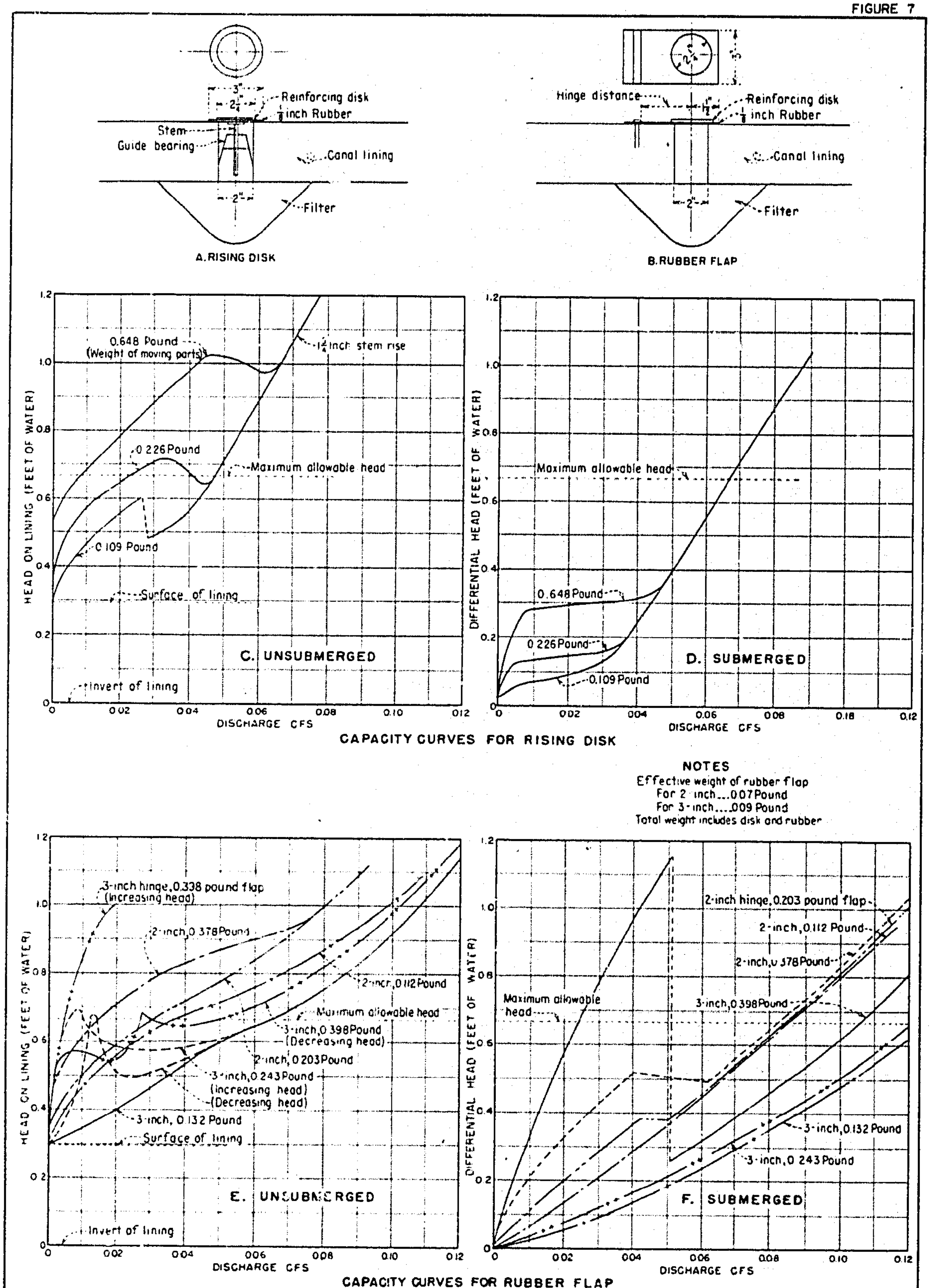
CAPACITY CURVES FOR UNDERDRAIN FLAP VALVES
FRIANT-KERN CANAL



6 - Inch drainpipe
Water surface
4.34"
3¼ by 7-inch flow passage
Weight 1.5 pounds
4" by 7¾" by ⅛" brass flap
Pipe Piezometer
Critical head for pipe flow passage
2-inches above surface of bottom lining
(based on 8-inch lining uplift pressure)
a. Discharge curve 6-inch drainpipe, valve attached (Based on head at pipe piezometer)
3-Inches
4-Inches
b. Discharge curve, drainpipe and flap valve flow passage inverts same elevation
Invert 6-inch drainpipe flow passage
Valve opening head = 0.06 foot
Invert valve flow passage
HEAD ON VALVE PASSAGE INVERT (FEET)
HEAD ON DRAIN PASSAGE INVERT (FEET)
DISCHARGE CFS
0
.02
.04
.06
.08
.10
.12
.14
.16
.04
.08
.12
.16
.20
.24
.28
.32
CAPACITY CURVES FOR
RECTANGULAR FLAP VALVE
FRIANT-KERN CANAL

FIGURE 6

FIGURE 7



CAPACITY CURVES FOR UNDERDRAIN WEEPHOLE
FRIANT-KERN CANAL