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UNDERDRAIN PROTECTION OF 3-1/2-INCH REINFORCED CONCRETE CANAL LINING

by

Jack C. Schuster

Problem

An increasing number of the Bureau of Reclamation supply canals are being designed with a 3-1/2-inch reinforced concrete lining, particularly where water is very valuable. These linings 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 water table or rainstorm, 6-inch open-jointed sewer pipe drains have been provided beneath the floor of the canal where these conditions are likely to exist (Figure 1). At intervals along the course of the canal, the drain pipes pass upward through the bottom lining and are vented by flap valves. Each valve consists of a body connected to the drain and a flap which is hinged at the top and is free to swing out from the body seat when internal pressure from the drain pipe acts upon it. In these drain systems, the invert of the valve flow passage is placed above the upper surface of the bottom lining in order to facilitate the installation of the valve. For safety of the lining with the valve in this position, the valve must open and be capable of discharging the drainage flow at heads much less than the buckling pressure of the lining.

To assure proper operation of the underdrain system it became necessary to (1) buy or design a flap valve that would be adequate for handling the flow of seepage water from beneath a canal lining without exceeding the lining buckling pressure, and (2) to provide a protection for this flap valve that would prevent silt deposition against the flap valve and that would prevent malfunctioning of the valve flap due to biological growth. Since little was known of the operating characteristics of flap valves and underdrain systems at small heads, two studies were made: an hydraulic study of (1) commercial and bureau designed flap valves and (2) a means of protecting the installed valve.

Electric analogy

The capacity of a canal underdrain system is limited by the elevation of the drain pipe exits and the resistance of the flap valves, therefore it was very important to determine the quantity of seepage flow that might be expected to enter the underdrains. To determine this quantity, tests were made in an electrical analogy tray (Figure 2A).

The equation $Q = KHLB$ may be used for computing seepage flow to the canal underdrains providing all of its factors can be evaluated.

Q = volume per unit time (cfy)
K = percolation rate (feet per year)
H = height of water table in feet above drain filter
L = length of canal section in feet, measured along longitudinal centerline
B = shape factor, dependent upon design and foundation conditions

The factor B cannot be determined from physical measurement of an installation but can be obtained through electric analogy studies in a conductor, analogous to flow of water through granular material (Ohm's Law and Darcy's Law for seepage flow). In the case of the electrical analogy tray, B 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).

$$\frac{R_m}{R_u} = \frac{L}{X-L}$$

L = length of resistance wire from slide wire bridge Figure 2A.
X = total length of resistance wire

Two conditions have to be considered in determining the value of B: (1) the effect of changing the depth to an assumed impervious layer; and (2) the effect of changing the height of the water table above the underdrain filter. These conditions were based upon the gradual lowering of the canal water level allowing the drains to reduce the ground water pressure on the lining. A flow net constructed by using data from the electric analogy tray will indicate the distribution of flow to the underdrain pipes used across the width of the canal. A precision resistance and voltmeter is placed in the electrical line leading from the electrodes representing the drains for a determination of flow distribution. A determination of the pressure distribution on the lining may also be made from the flow net if it is desired. It may also be pointed out here that values of B and pressure obtained for an arrangement are applicable only to canal cross sections geometrically similar to that tested.

Flap valves

With the approximate seepage flow quantities and distribution determined; it became necessary to find a valve that had sufficient capacity to discharge this flow, which for assumed maximum values in the above equation amounted to 0.80 cfs, within the required head range for two conditions (1) when the canal was empty and (2) sufficient water in the canal to submerge the valves. Four commercial valves were obtained for this purpose. In a preliminary investigation it was found that all of these valves required an excessive head to open when the canal was empty and they were unsubmerged, which would definitely limit the capacity of the underdrain. Since all of the commercial valves were of similar design, two were selected to be altered and studied for possible use in the underdrains.

A head-discharge curve for complete submergence was obtained for the National Cast Iron Pipe Company flap valve (Curve a, Figure 3A). That the differential head required to maintain flow was independent of depth of submergence was checked and the capacity was found adequate.

For the unsubmerged valve (Curve a, Figure 3B), the head to open was excessive, and 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 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 when the opening was very small. A decrease in pressure in the flow passage accompanied the contraction and expansion and created a hydraulic downpull 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 flap by the force of the water changed the dimensions of the flow passage so that the jet became aerated. When aeration occurred, the flap moved out and the head in the pipe decreased. To eliminate the hydraulic downpull force on the flap, the seat ring was machined to an annular ring having a width approximately one-fifth as great as the original. The discontinuity was eliminated as can be noted in Curve c (Figure 3B).

Several alterations were made to the valve with the resulting change to the valve capacity shown in Figure 3.

The alterations were:

1. A flap counterbalance added to the upstream side of the valve flap decreased the head required to open and increased the capacity. This was not used because of the cost of modifying each valve.

2. The weight of the flap was partially responsible for the large head needed to open the valve. An investigation was made to reduce the weight of this flap with a resulting decrease in opening head and increase in discharge.

3. To further increase the capacity of the valve, the hinge of the light weight flap was moved near its center of gravity.

The changes and the resulting improvement in discharge and head required to open are shown in Figure 3.

Rectangular Flap Valve

Since it was found that all of the commercial flap valves were unsatisfactory for installation in low pressure underdrain systems, a rectangular flap valve was designed on the basis of the results obtained from the hydraulic tests. This flap valve (Figure 2B) included a cast iron body that lowered the invert of the valve flow passage to within 1-1/4 inches of the canal lining, 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 1/4-inch. A clearance of 1/16 inch between the hinge pin and bearing was provided to minimize the possibility of an electrolytic 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 this valve was 0.06 foot of water (Figure 4).

Hoods

With the development of a valve hydraulically suitable for installation in underdrain systems, it became evident that this valve must be protected from impact of canal cleaning equipment because of its light construction. Provision must also be made for preventing silt or biological growth causing a malfunctioning of the flap. Any type of debris collecting against the valve flap would increase the head required to force it open and would thus endanger the canal lining.

It was planned to protect this flap valve by using an unreinforced concrete hood to be cast integral with the canal lining. At the start of this study, it was realized that very few quantitative results could be obtained. The quantity and distribution of silt and biological growth to occur in the canal was unknown. The particle size of wind-blown sand in the canal could be assumed small and easily moved by the velocity of the water at which the canals operate. The size of the earth material moved into the canal from an inlet by a rainstorm could include small rocks. The smaller particles would probably be moved by the canal water while the larger rocks would remain where deposited. These rocks would cause no trouble to the underdrains unless they covered the hood and valve. Biological growth occurring in the canal was simulated by water-soaked cotton streamers. Waterweeds and algae were also used.

The original hood design (Figure 5A) was constructed full size because it was not known whether the scavenging ability and scour pattern would be the same for both full size and model. To obtain comparable results in the preliminary tests, a uniform depth of 3/4 inch of sand (1/8-inch maximum size) was placed around the hood. Some canals will be operated at velocities as low as 1 foot per second, thereby making it necessary for the hood to operate satisfactorily at this water velocity. After operating for 1 hour at an average velocity of 1 foot per second, the resulting scour pattern for the original hood was as shown in Figure 5A. A maximum height of 1-7/8 inches of sand was deposited immediately in front of the valve opening. With the sand deposited in this region, it was felt that this hood was unsatisfactory. A 1:4 scale model test of the same hood bore out these results to a remarkable degree, a comparison of which is shown in Figure 5B.

Five types of hoods were studied in finding one considered to be satisfactory (Figure 6). They were:

1. Original hood discussed above

2. Elliptical hood

   a. Elevation section an ellipse
   b. Side-mounted flap valve
   c. End mount of flap valve

3. Enclosing hood

   a. Valve to be mounted inside
   b. Vent provided to allow water to pass to the canal

4. Circular hood

   a. Side-mounted flap valve
   b. Deflector for protecting valve
   c. Slot for increasing scour

All of these hoods failed to provide a satisfactory scavenging action for silt and biological growth.

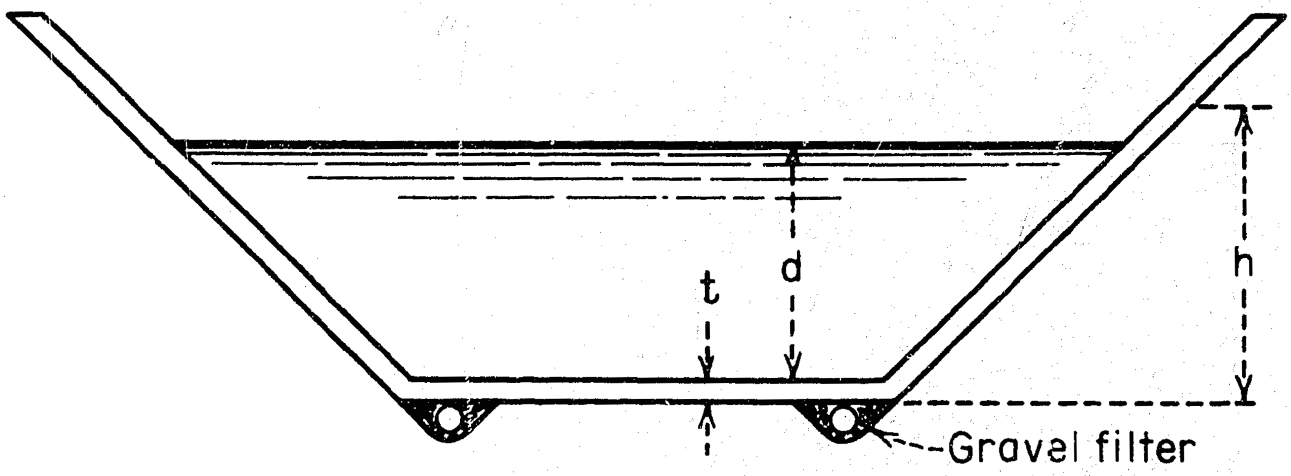
5. Two-piece hood

During the investigation of the original hood, a series of tests; using deflectors as an aid in removing sand, was carried out. None of the deflectors projected above the top of the hood, the thought being that biological growth flowing with the water could easily become entangled upon the deflector. A decision was made to attempt the use of a downstream deflector that did project above the upstream hood piece. In doing this a compromise between a complete sand scour and the entanglement of some growth on the deflector was accepted. The height of projection of the deflector above the upstream hood piece was based upon the completeness and rapidity with which the area between the deflector and hood was scoured.

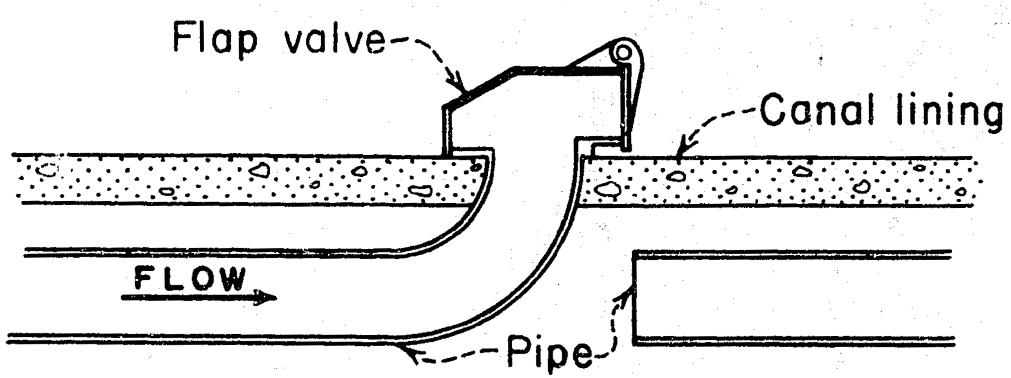
A 12-inch wide deflector, straight in profile, projecting 3 inches above the upstream piece, and with an upstream angle of 69° with respect to the canal floor produced the best scouring action (Figures 6E and 7A). In cleaning the canal of biological growth on the bottom, a log chain is dragged upstream by the means of two jeeps or tractors. To ease this chain up and over the protective hood, the downstream piece of the deflector was placed on a 30° slope. Also two bronze rods were cast into the concrete of the upstream and downstream pieces of the hood to prevent the chain from dropping into the space between them.

The scouring for the two-piece hood starts at the apex of the angle made by the canal floor and the deflector face of the downstream section of the hood. A roller of water resulting from the deflected portion of the flow had sufficient velocity to keep the sand in suspension between the hood pieces. This sand was gradually ejected from this area by the efflux of water from both sides, thence it was moved downstream by the water passing the side of the hood. The scouring proceeded rapidly over approximately 7 inches of the distance between the hood pieces and was retarded slightly over the remaining inch. It must be realized that the sand was deliberately placed between the hood pieces, and probably would not occur in the field, for the laboratory tests showed no tendency for canal sand to re-enter the space once it was ejected. This hood was also tested for its ability to pass biological growth. The growth in small quantities was caught by the bronze rods, a short length of the streamer (approximately one-eighth or less of the total length) entered the space between the hood pieces. The longer section of the streamer was carried downstream where the chain drag would tear it off. When growth was deliberately placed in the space between the hood pieces, it was rolled about and finally ejected out the sides showing no tendency to become entangled.

The two-piece hood was entirely free of sand except for the areas near the upstream and downstream ends as shown in Figure 7B.



CANAL SECTION



UNDERDRAIN SECTION

VALVE UNSUBMERGED

$$h\gamma_w = t\gamma_c$$

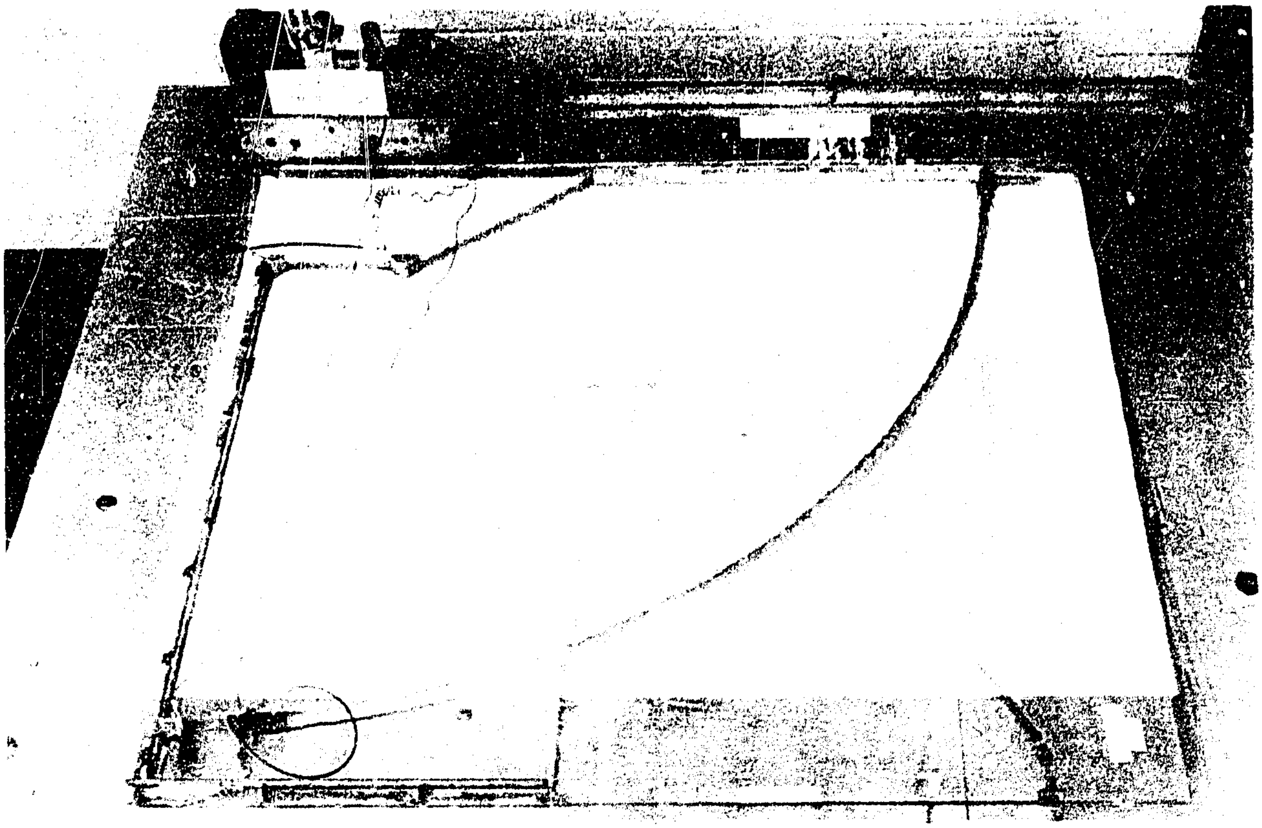
$$h = \frac{t\gamma_c}{\gamma_w}$$

VALVE SUBMERGED

$$d\gamma_w + t\gamma_c = h\gamma_w$$

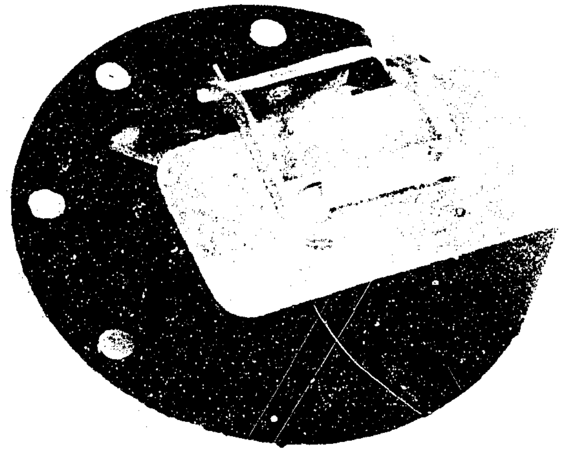
$$h - d = \frac{t\gamma_c}{\gamma_w}$$

Figure 2



A. Electrical Analogy Tray.

1



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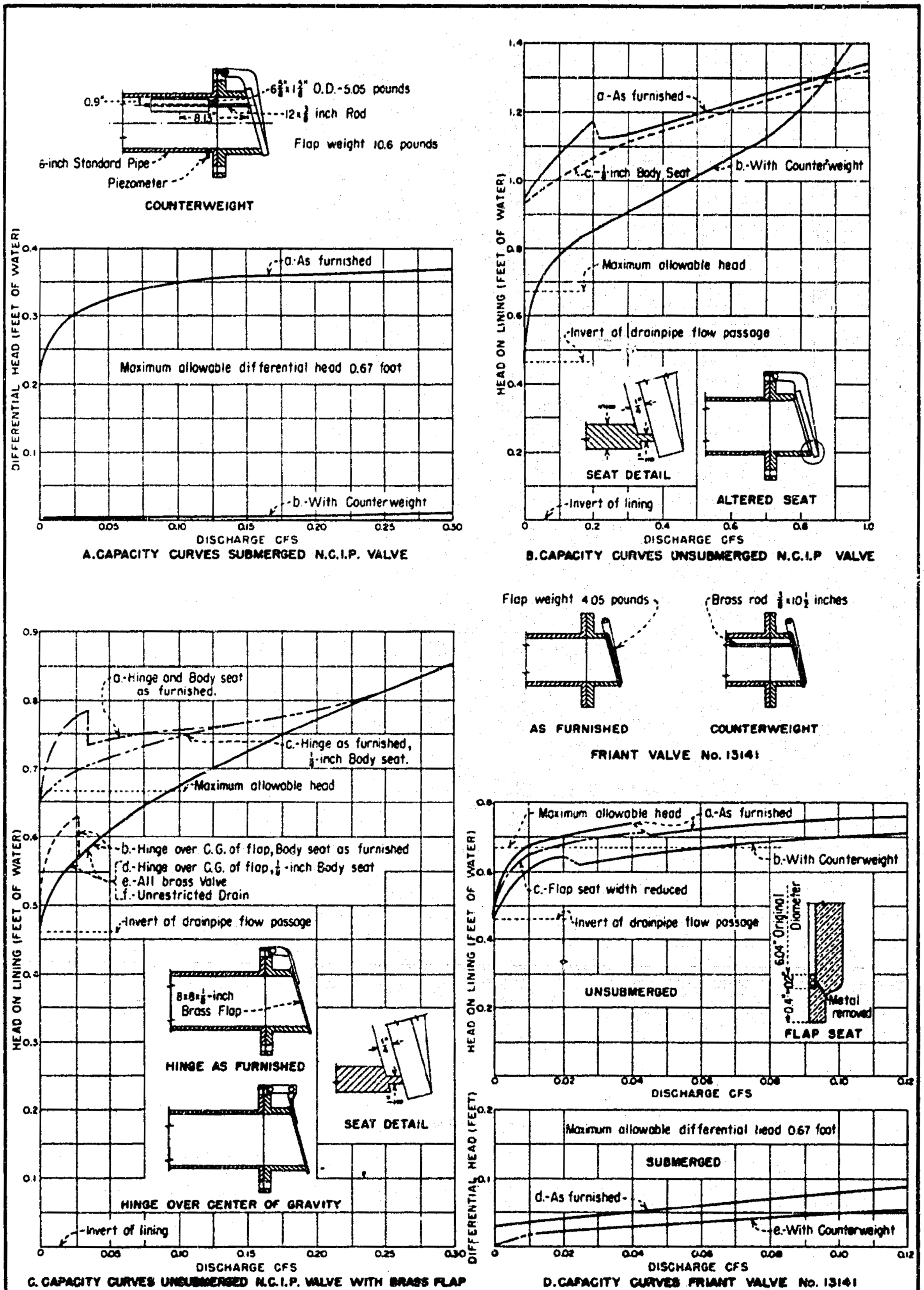
B. Commercial Valve. Recommended Valve.

FIGURE 3



CAPACITY CURVES FOR UNDERDRAIN FLAP VALVES
FRIANT-KERN CANAL

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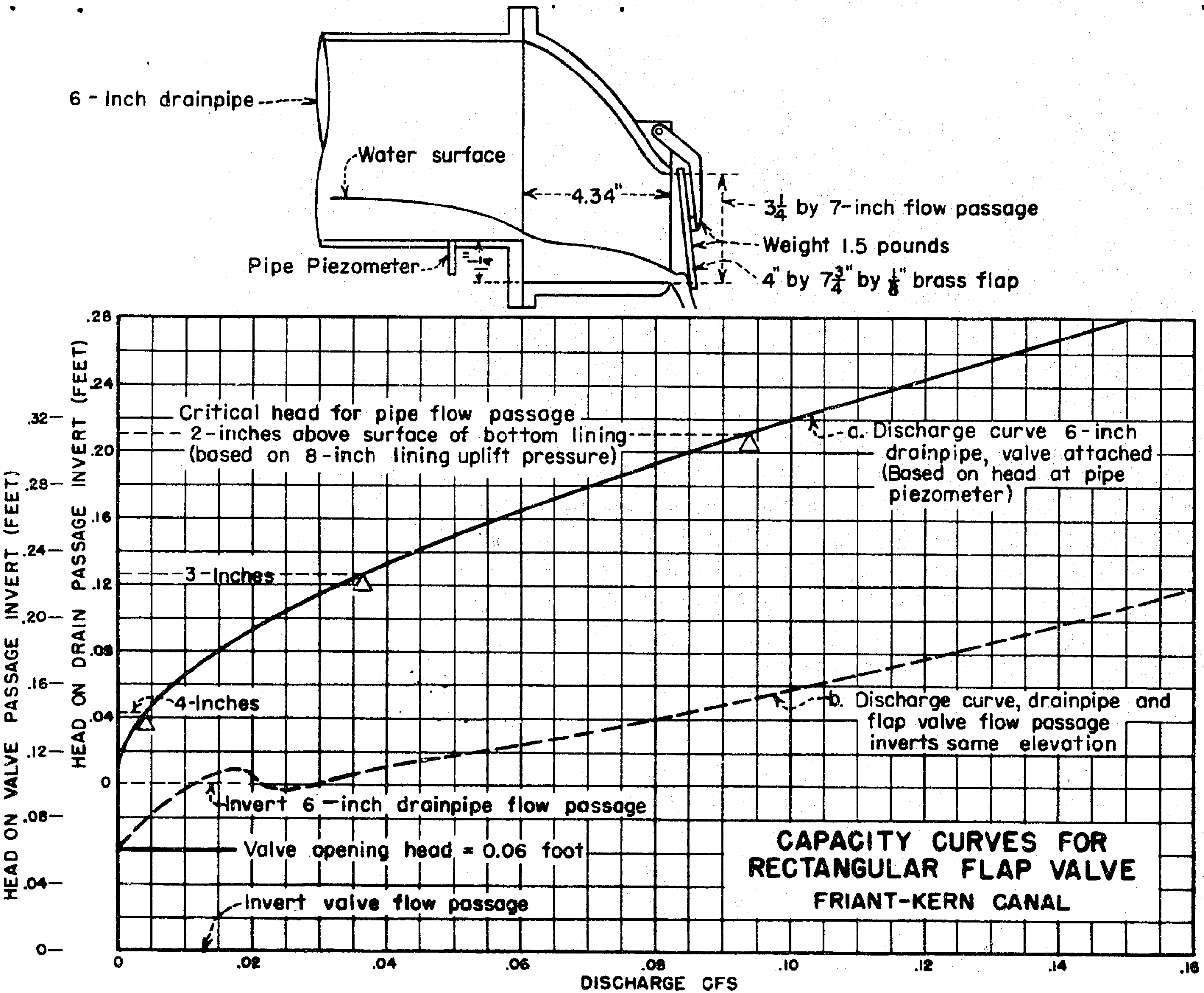


CAPACITY CURVES FOR RECTANGULAR FLAP VALVE

FRIANT-KERN CANAL

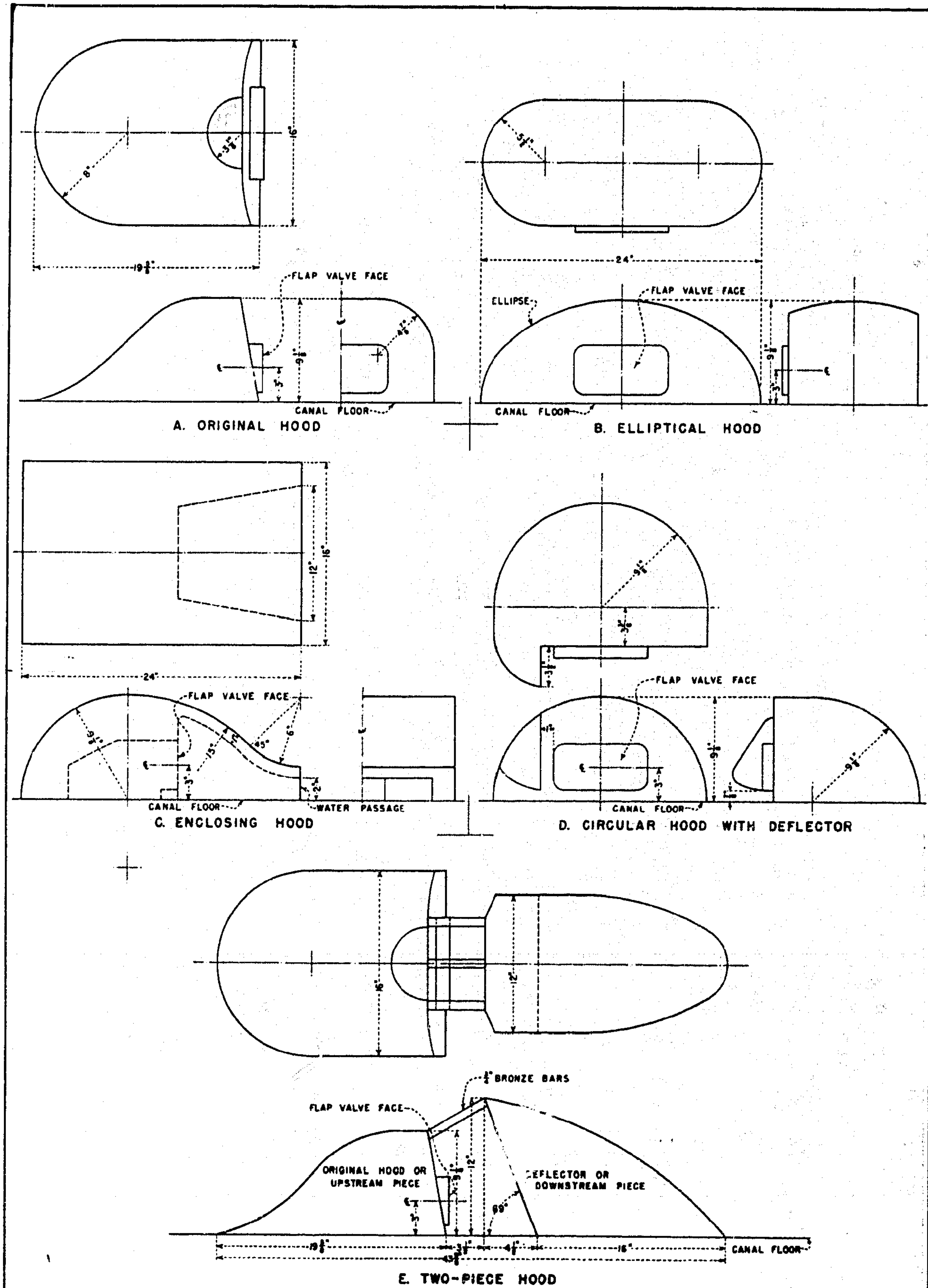
FIGURE 4

316.4

Figure 5

A. Scour pattern for full sized hood.

B. Scour pattern of 1 to 4 scale model of recommended hood-continuous sand movement.



CANAL UNDERDRAIN PROTECTIVE HOODS

FLAP VALVE PROTECTIVE HOOD STUDY

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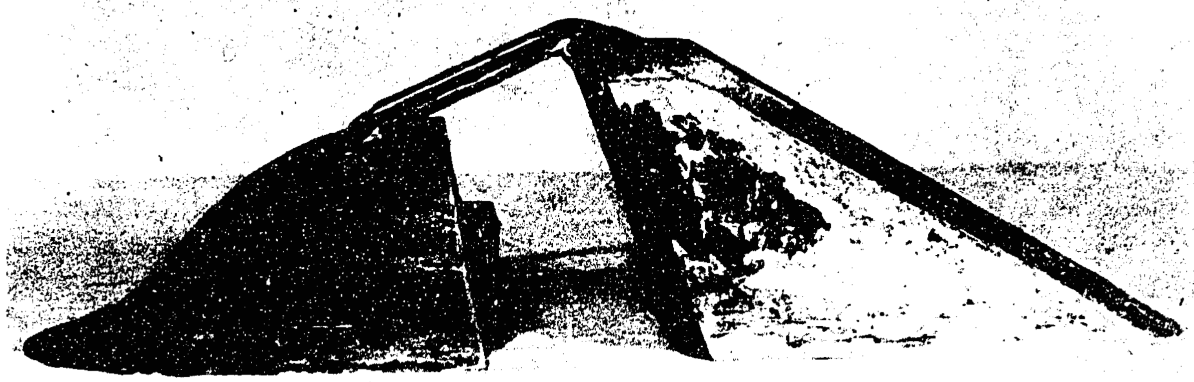
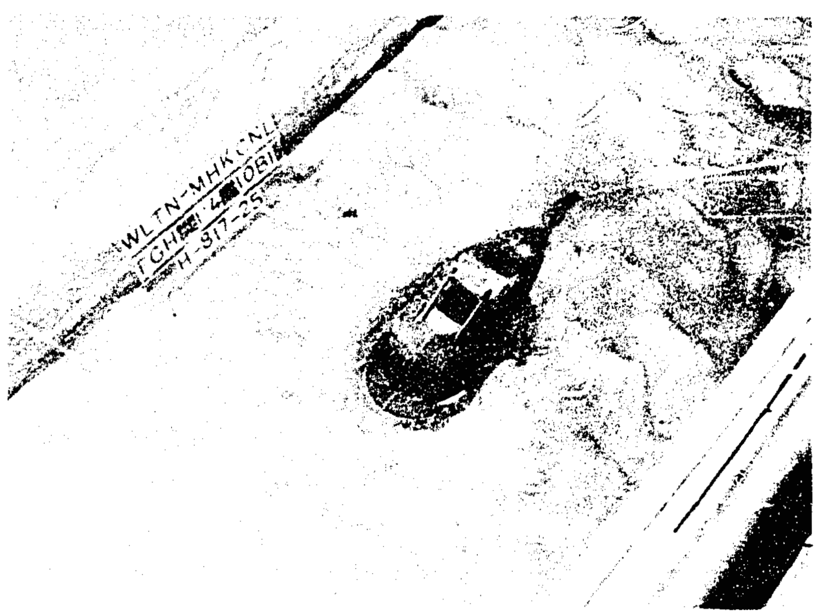
Figure 7



A. Profile of 1 to 4 scale model of recommended hood.



B. Scour pattern for 1 to 4 scale model of recommended hood-continuous sand movement.