

PAP-559

**UNDERWATER LINING
OF OPERATING CANALS**

BY

JERRY R. FITZWATER

PAP-559

UNITED STATES GOVERNMENT

Memorandum

Denver, Colorado
DATE March 9, 1989

TO : Memorandum
Chief, Water Conveyance Branch

THROUGH : Chief, Research and Laboratory Services Division
Chief, Civil Engineering Division JDS 3-29

FROM : ACTING
Chief, Hydraulics Branch

SUBJECT : Underwater Lining of Operating Canals (Hydraulic Research)

The Hydraulics Branch participation in the subject tests is summarized in the enclosed memorandum report by Jerry Fitzwater.

The tests covered three areas:

1. Studies conducted in our 4-ft-wide permanent flume and in a smaller portable flume to determine erosive characteristics of flowing water on the fresh concrete.
2. Mathematical simulation of flow in the Coachella Canal to determine velocities near the slip form equipment.
3. A 1:5 demonstration model of the Coachella Canal used to develop and demonstrate placement methods for prospective contractors.

Clifford A. Pugh

Enclosure

cc: D-3120 (Johnson) (w/encl), D-3730 (w/encl), D-3740, (w/encl)
D-3750 (w/encl), D-3750A, (w/encl), D-3751 (PAP file) (w/encl)
D-3752, (w/encl), D-3752 (Fitzwater), (w/encl)

WBR:JRFitzwater:flh:3/9/89:236-6156
(Misc.correspondence:3752:019)



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UNDERWATER LINING OF OPERATING CANALS

By Jerry R. Fitzwater
February 1989

Background

The U. S. Bureau of Reclamation and two large California water agencies, Coachella Valley Water District and Metropolitan Water District of Southern California, have agreed to test a method of lining earthen canals without draining them. Since completion of the laboratory tests, the Bureau of Reclamation has awarded a contract for lining a 1-1/2-mile prototype section of the Coachella Canal to verify the constructability of the underwater placement of a 30-mil PVC membrane and 3-inch monolithic slip formed concrete protective cover.

This concept evolved from a design review for relocating the All American Canal. The relocation design was based on a conventional concrete lined canal being constructed adjacent to the existing canal. The reviewers began to examine the possibility of a geomembrane with earth cover in the existing canal, noting that considerable savings could be realized over the relocation plan. Further discussion with the districts indicated an earth cover was not desirable and that a hard surface lining was the preferred alternative to facilitate anticipated canal cleaning. Investigations into the possibilities of using a concrete cover to hold down the geomembrane began several months later.

Several areas of study were identified to answer questions about underwater placement of a concrete liner.

1. Mix design for placing a concrete canal lining underwater (D-3730).

The mix design study examined the effects of cement content and various admixtures such as: class F and class C fly ash, bentonite, air entrainment, and anti-washout admixtures (AWA) on the properties of the fresh and hardened concrete. The relevant concrete properties are: cohesiveness, slump, slump loss, unit weight, and air content. After curing, the concrete properties of interest are: compressive strength, freeze and thaw durability, and sulfate resistance.

For the backfill concrete, soil with the same gradation as bank-run soil along the canal was considered. A mix design was developed to produce concrete which was cohesive enough for placement in flowing water yet economical enough to be used for backfill. The required cement content and the effect the high percentage of fines in the soil needed to be determined. The fresh and hardened concrete properties were the same as in the canal lining mix. Testing was conducted by D-3730.

2. Small-scale testing of underwater canal concrete placement.

The purpose of the small-scale test was to look at the possible placement methods and determine the concrete property requirements. In examining the placement method, it was necessary to look at the shape of the slip form, the speed of placement, the finish, and the concrete consolidation. The concrete properties investigated included: the underwater cohesiveness of the concrete, the slump required to place underwater, placeability, washout, and the concrete's ability to maintain its shape. Testing was conducted by D-3730.

3. Erosion testing.

The purpose of the erosion test was to determine the loss of fresh concrete under flowing water and determine the variables affecting the loss. At this point the testing had been narrowed to two mix designs - a canal lining mix design and a backfill concrete mix design. The mixes were tested at various depths of submergence with water flowing at 0.5, 1.0, 2.0, and 3.5 feet per second. The erosion testing was conducted jointly with D-3730, D-3740, and D-3750 in the hydraulic laboratory's 4-foot flume.

4. Large-scale testing and demonstration model.

This phase included construction of a 1:5 scale model of one half section of the Coachella Canal in the hydraulic laboratory and the design and fabrication of a slip form, see figure 1. Tests were conducted to determine the best placement methods, shape of the slip form, the speed of placement, the finish, and the concrete consolidation. Upon completion of the testing, the model was used to demonstrate a typical placement for the prospective contractors. Design and testing was conducted jointly by D-3730, D-3740, and D-3750.

5. Impact on water quality from the in-place lining of the Coachella Canal.

Three water quality parameters were identified as potential areas of concern during the concrete placement process: turbidity levels, pH levels, and water temperature levels. During the erosion tests, the water upstream and downstream of the test area was tested for turbidity rise and change in pH. All of these levels were evaluated by D-3740.

6. Underwater canal lining - numerical flow studies

A numerical model study of a cross section of the Coachella Canal was conducted to estimate velocities around the slip form. These data were compared to the washout velocities determined in the erosion testing. The numerical modeling was conducted by D-3750.

7. Laboratory evaluation of PVC lining for Coachella Canal.

It was determined that 30-mil PVC membrane lining will be required in the field with the possibility of using a geotextile material between the PVC lining and the 3-inch concrete protection. Testing of these membranes was conducted jointly by D-3730, D-3740, and D-3750 and evaluated by D-3740.

Hydraulics Branch Laboratory Studies (D-3750)

The Hydraulics Branch was involved with several aspects of the study, including the erosion testing in the hydraulic laboratory's 4-foot-wide, 8-foot-high, 40-foot-long flume. A ramp was designed to place the removable samples on the floor of the flume, see figure 2. Mix designs for the fresh underwater concrete had been determined by D-3730 prior to the erosion tests. Six tests, with two concrete samples for each test, were run for 4 hours each while velocities and head measurements were taken. Flow velocities for testing were 0.5, 1.0, 2.0, and 3.5 feet per second. These data were recorded and plotted for each test, see figures 3, 4, 5, 6, 7, and 8. During each test, video footage was taken to monitor the erosion taking place. Samples of the water were taken downstream of the concrete samples to monitor the rise in turbidity and the change in pH. Results from these tests are given in the report "Impact on Water Quality from the In-Place Lining of the Coachella Canal" by D-3740.

Additional erosion tests were also conducted in a portable sloping flume. In the sloping flume, samples contained in cylindrical containers were exposed to flow velocities of 1 and 2 feet per second. Tests were run for 4 hours each, and measurements of the amount of concrete erosion were taken after each test. Results of these tests can be found in the report "Mix Design Study for Placing a Concrete Canal Lining Underwater" by W. F. Kepler, D-3730.

Following the erosion tests, a scale model was built to determine the feasibility of actually placing concrete with a slip form and having it discharge underwater in a finished form. The model was a half section of the Coachella Canal at a model scale of 1:5, see figure 9. The model represented about 90 feet of length of the prototype canal with a 2-1/2:1 side slope. The slip form for the model was designed by D-3752 (see figures 1 and 10) and fabricated by a contractor. The slip form was designed to be held down on tracks to prevent lateral movement and also to prevent the slip form from rising off the tracks during the placement. The tendency to leave the tracks during placement was noticed during the small scale modeling done by D-3730. The form was advanced and held back with hand operated winches mounted on the model.

Three tests were necessary to establish the technique for placing the concrete, with a fourth test to demonstrate the placement for

the prospective contractors. The contractors were bidding for a contract to place a 1-1/2-mile test section in the field.

A two-dimensional fluid dynamics finite difference model was used to simulate flow velocities around the slip form. Results of this study indicated that the highest velocities would be about 4.90 feet per second around the edge of the slip form. Velocities of this magnitude could be taken care of by covering the concrete next to the slip form to prevent any erosion. Further results of this study are given in a memorandum "Underwater Canal Lining - Numerical Flow studies" by D-3752.

Conclusions

The overall test results indicated that placing of concrete underwater is a very real possibility. A prototype slip form is being designed by the successful contractor on the Coachella Canal demonstration project. Field results of the 1-1/2-mile test section on the Coachella Canal should be available after the spring of 1989. Success of this project could lead to numerous applications of the technology in the future and significant savings in water now being lost to leakage.

FIGURES

Figure

1. Canal lining slip form model
2. Form for concrete erosion study in 4-foot flume
3. Flow velocity vs. depth, erosion flume test No. 1
4. Flow velocity vs. depth, erosion flume test No. 2
5. Flow velocity vs. depth, erosion flume test No. 3
6. Flow velocity vs. depth, erosion flume test No. 4
7. Flow velocity vs. depth, erosion flume test No. 5
8. Flow velocity vs. depth, erosion flume test No. 6
9. 1 to 5 scale model of Coachella Canal
10. Photograph of concrete placement in 1:5 scale model

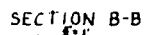

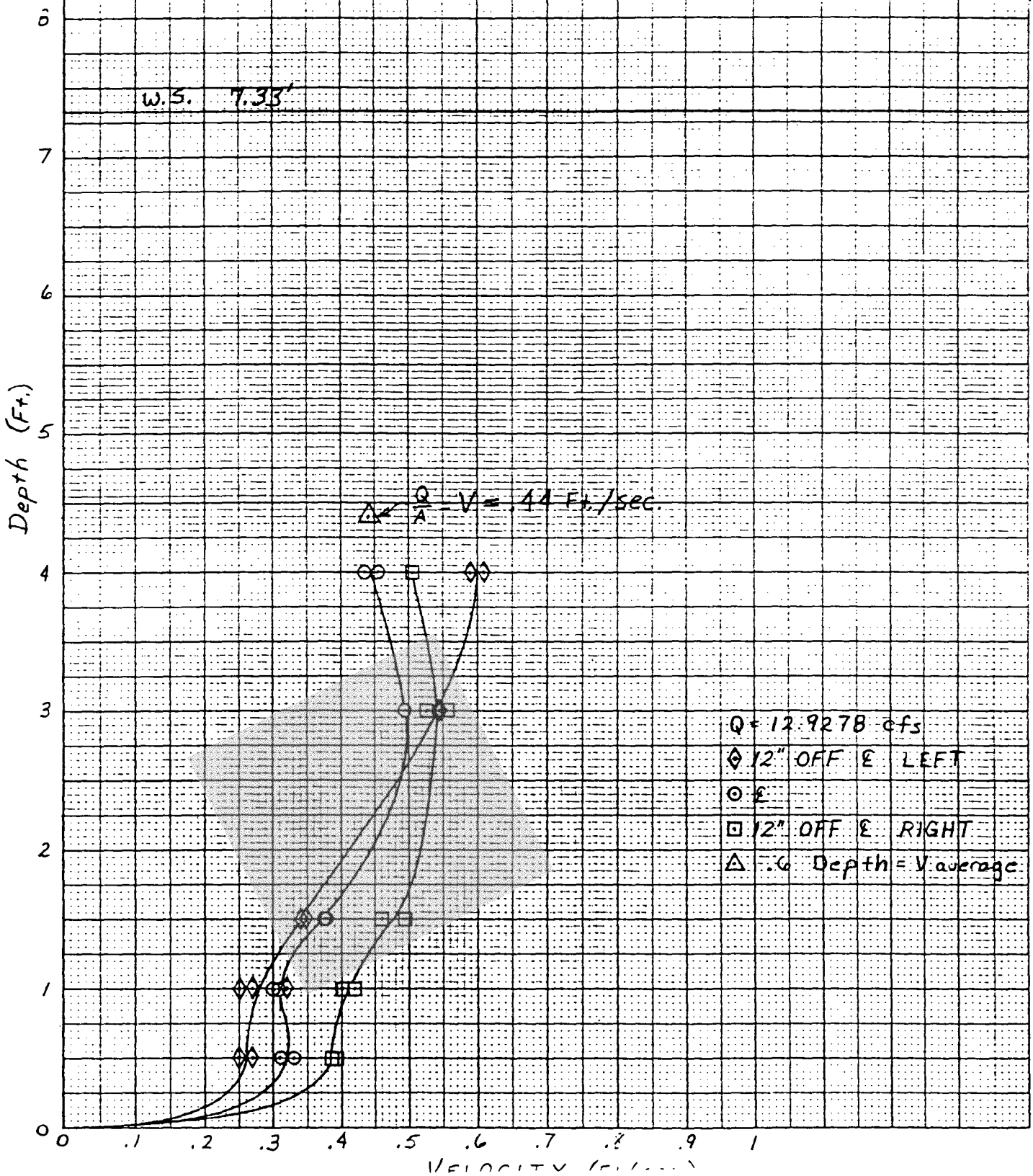


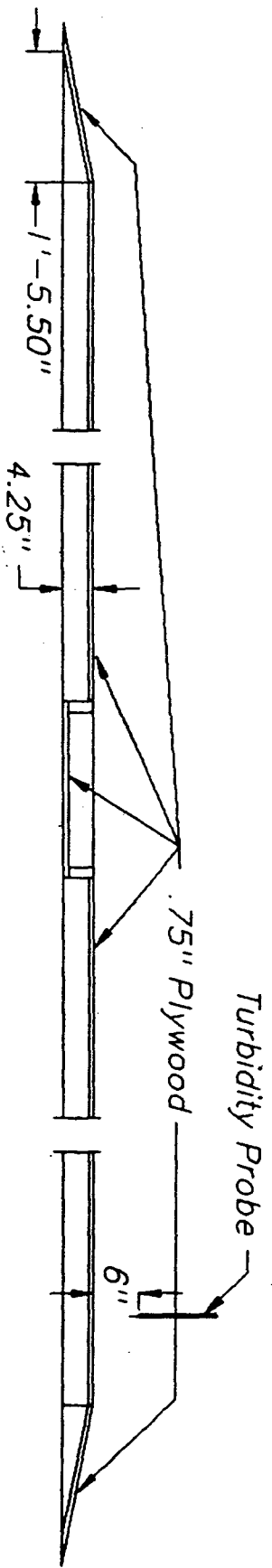
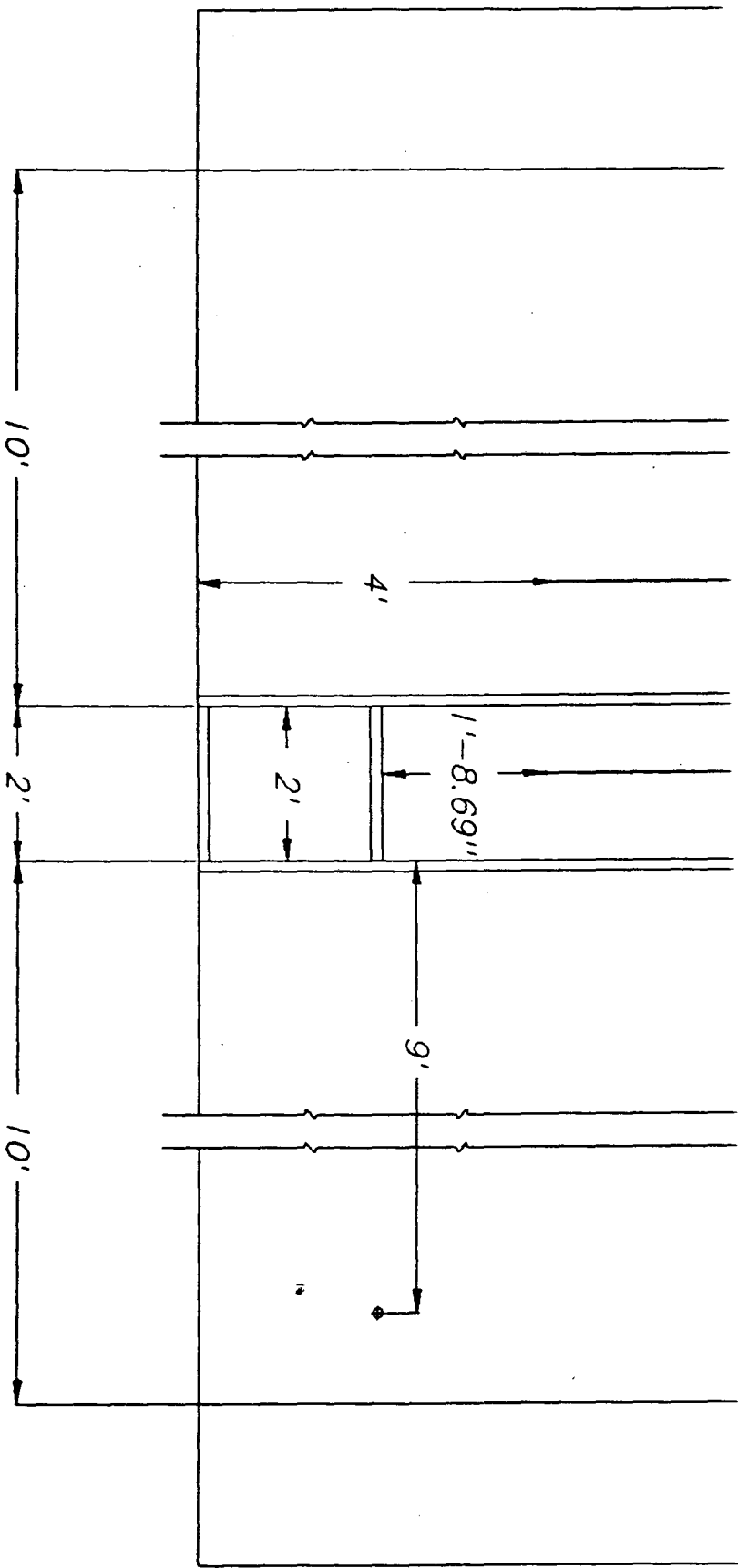
Figure 1

| | |
|---|---|
|  ARMY'S YOUR SAFETY | |
| UNITED STATES DEPARTMENT OF THE INTERIOR ARMY OF ENGINEERS | |
| CANAL LINING SLIP FORM MODEL | |
| DESIGNED: <i>J. J. Smith</i> DRAWN: <i>J. J. Smith</i> CHECKED: _____ | TECHNICAL APPROVAL: _____ SUPERVISOR: _____ APPROVED: _____ |
| MODEL NO. 66-1111 | DATE: 10-1-1966 |

EROSION FLUME TEST #1

FIGURE 3





FRESH CONCRETE EROSION FLUME
FLOOR SECTION

FIGURE 2

EROSION FLUME TEST #2

FIGURE 4

46 1320

K-E 10 X 10 TO 18 INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

DEPTH (Ft.)

8

7

6

5

4

3

2

1

0

W.S. 4.72'

$Q = 20.6970 \text{ cfs}$

◇ 12" OFF Σ LEFT

○ Σ

□ 12" OFF Σ RIGHT

△ @ Depth = V average

$Q = V$

$A = V$

$V = 109 \text{ ft./sec.}$

VELOCITY (Ft./sec.)

0

.1

.2

.3

.4

.5

.6

.7

.8

.9

1

1.1

1.2

1.3

1.4

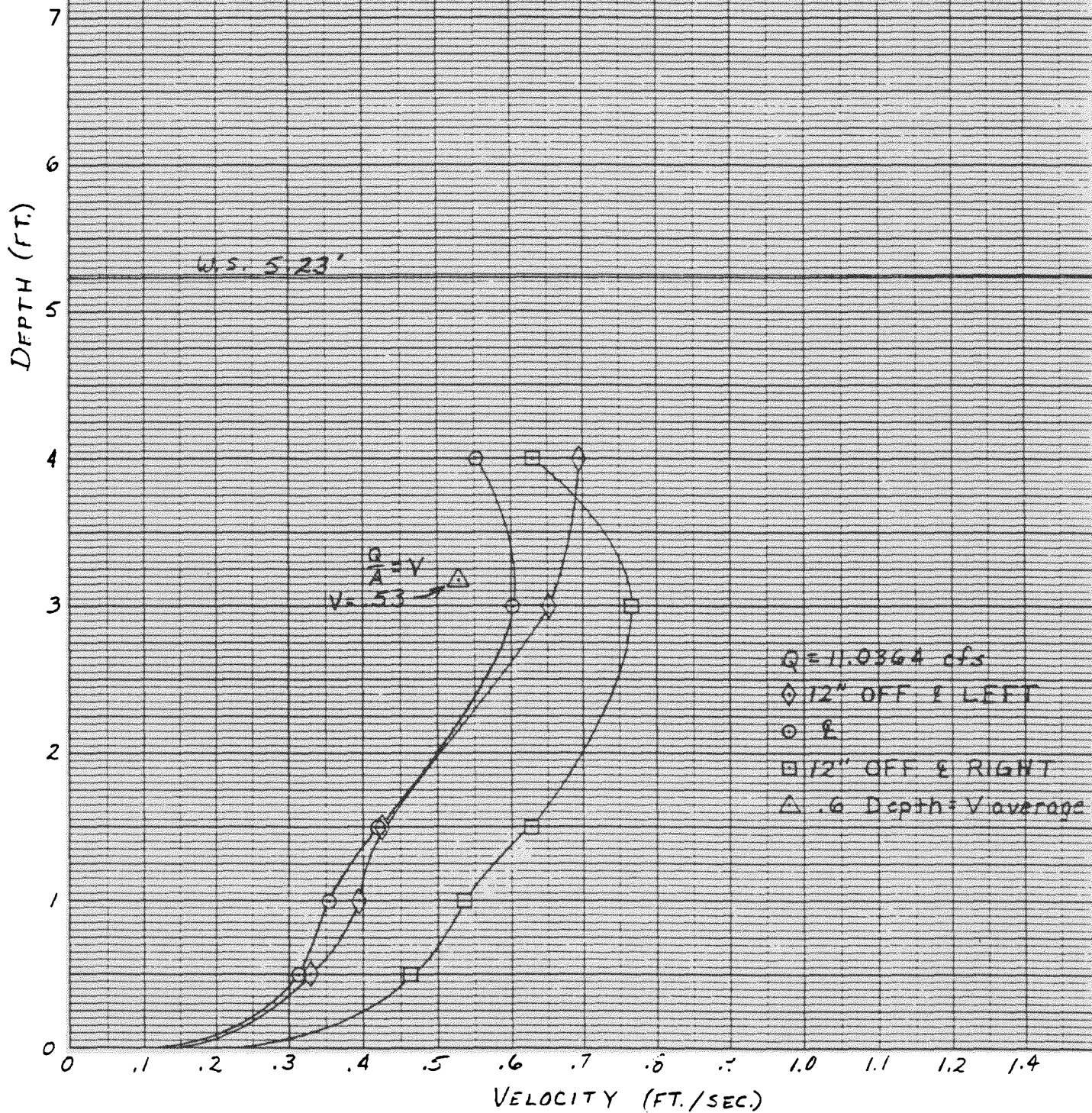
EROSION FLUME

TEST #3

FIGURE 5

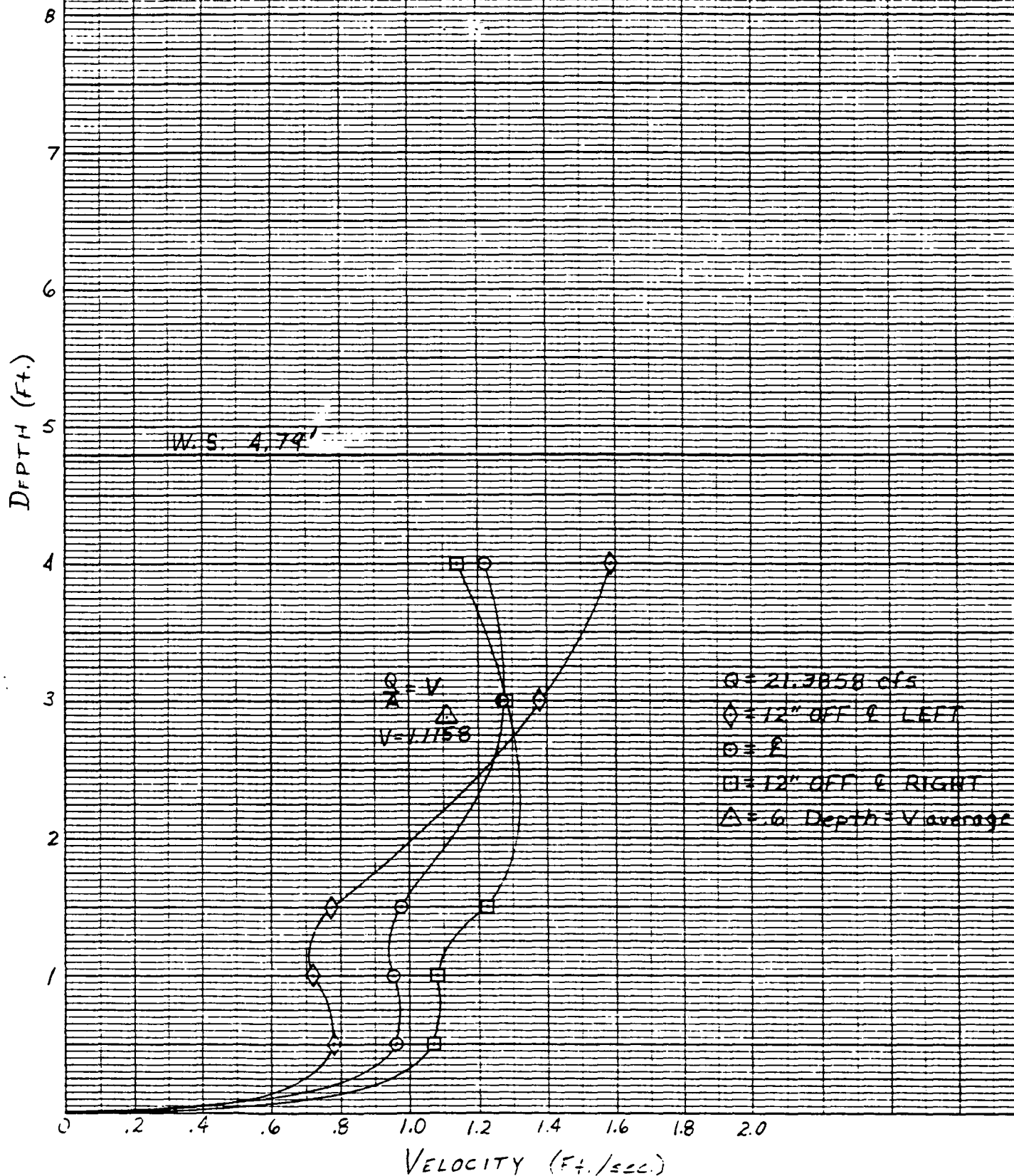
46 1320

K-E 10 X 10 TO 1/4 INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.



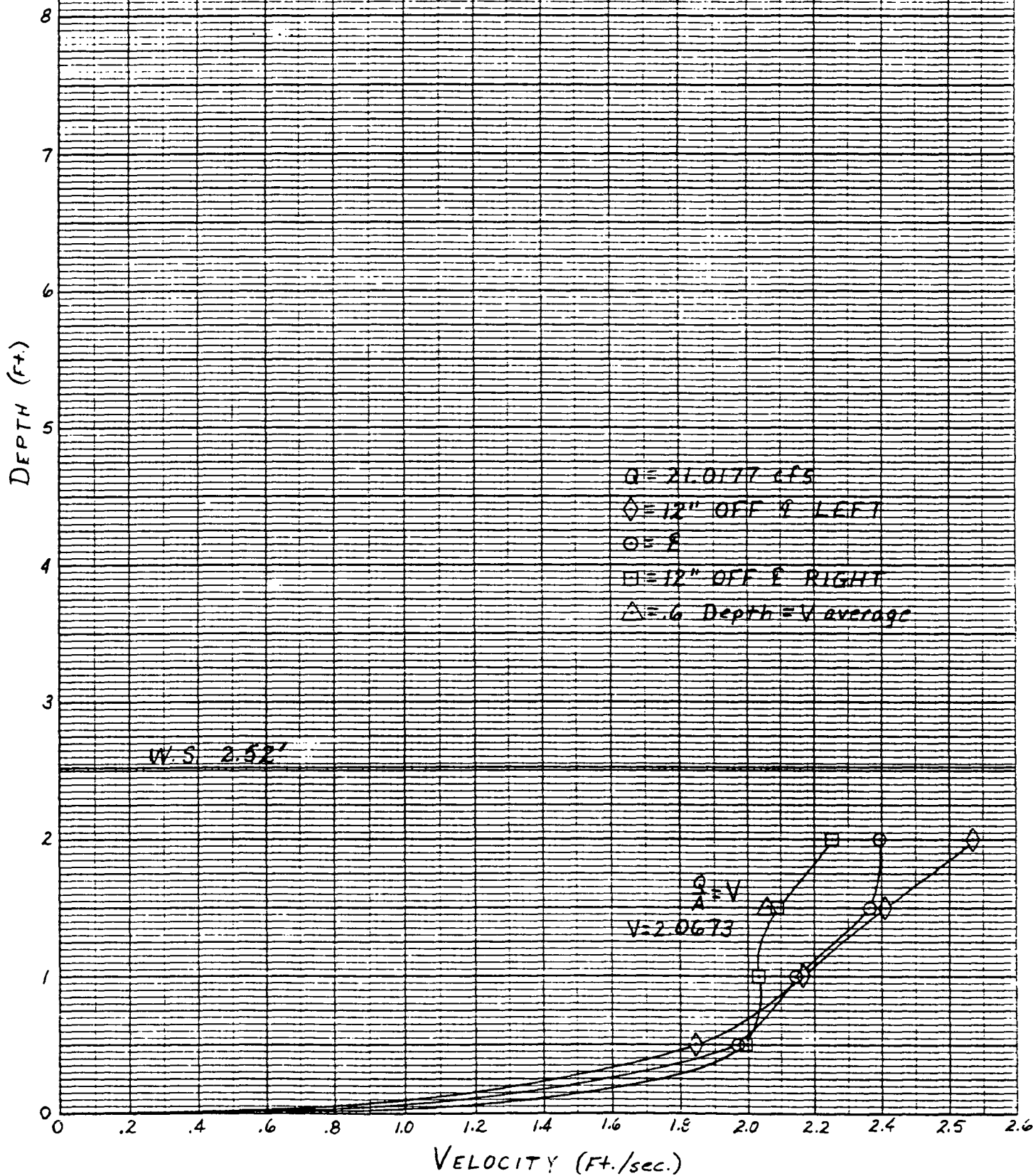
EROSION FLUME TEST #4

FIGURE 6



EROSION FLUME TEST #5

FIGURE 7



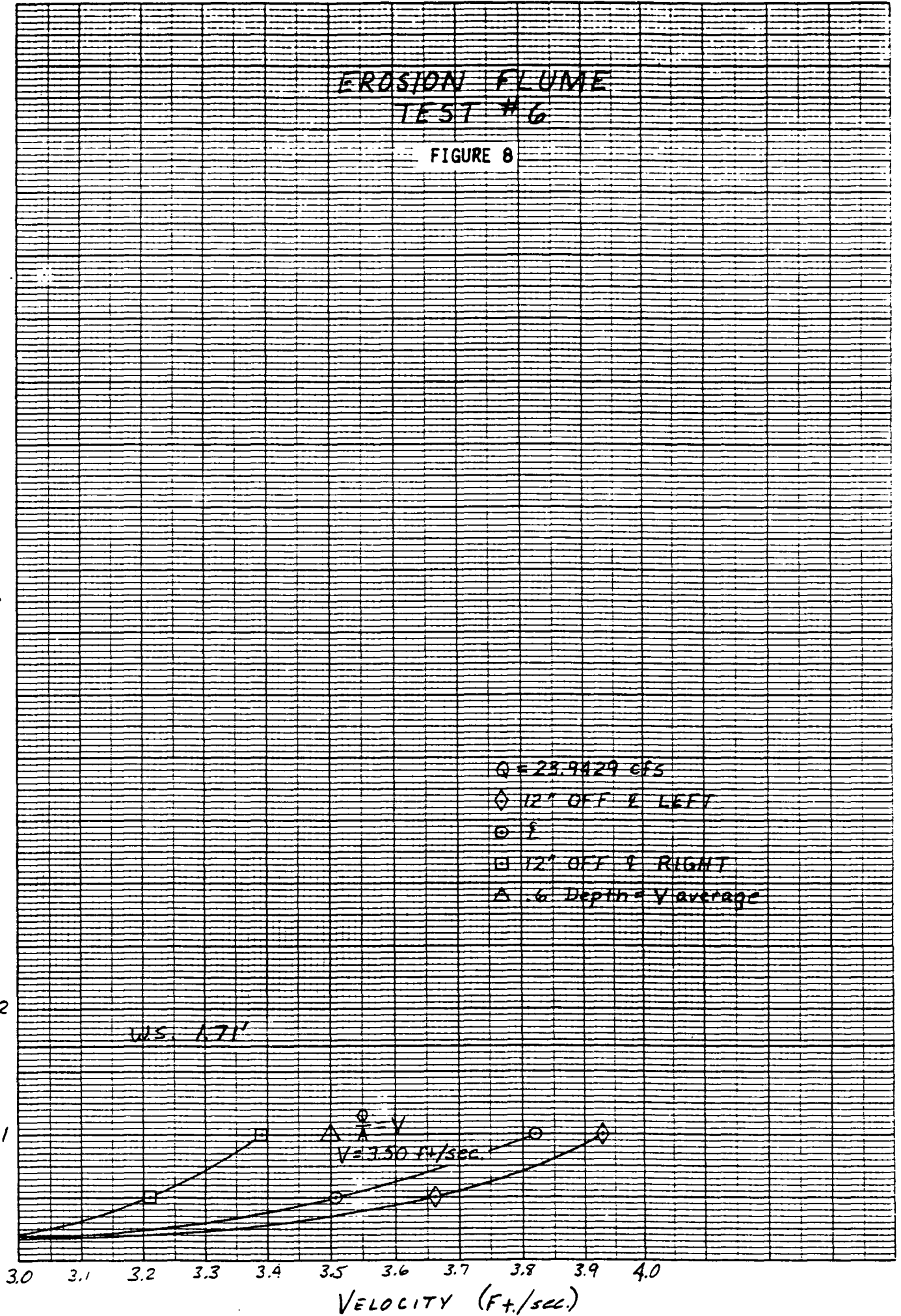
EROSION FLUME TEST #6

FIGURE 8

46 1320

K-E 10 X 10 TO 1/4 INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

DEPTH (Ft.)



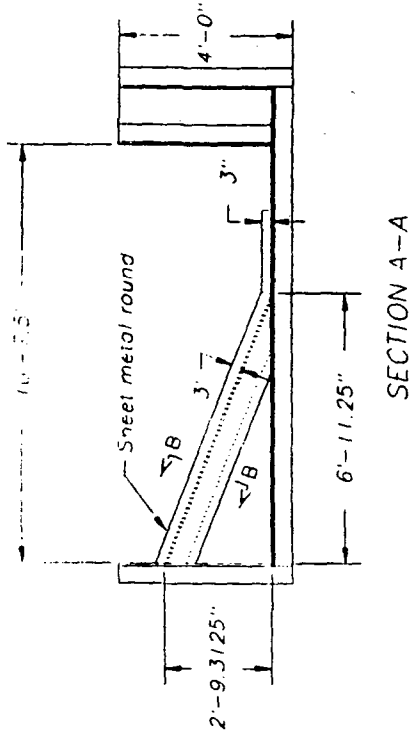
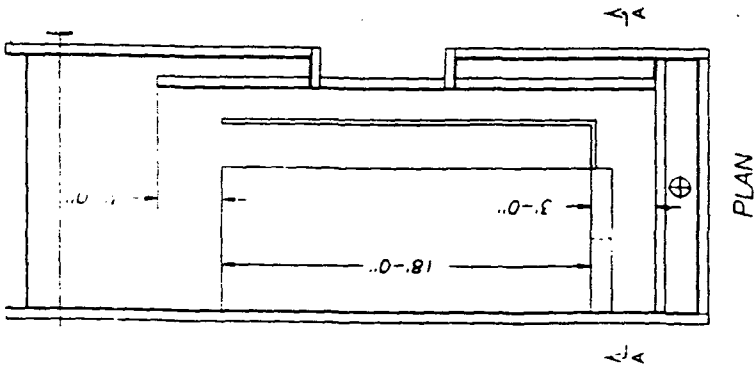
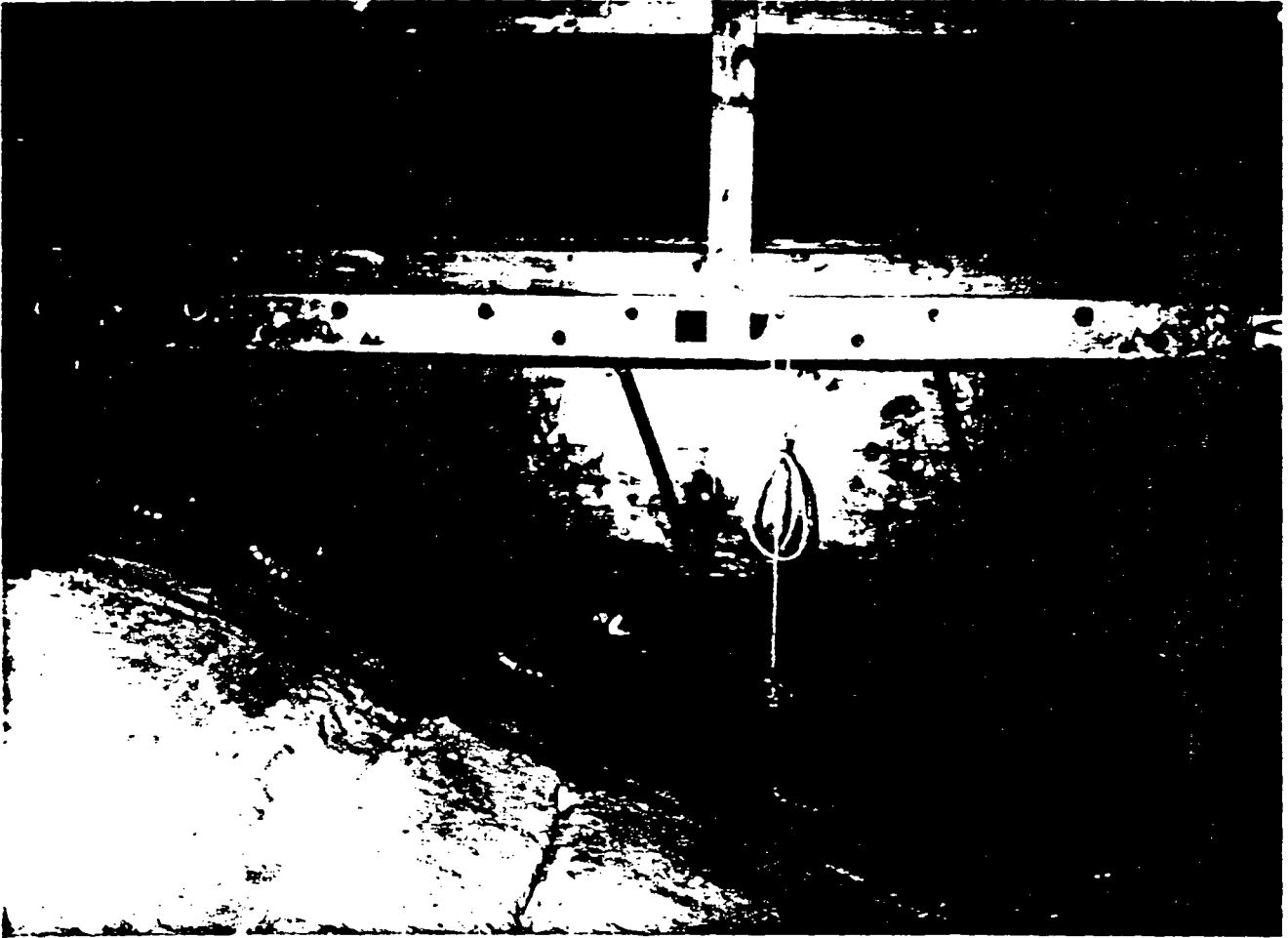


FIGURE 9

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 CANAL LINING
 MODEL

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 CHECKED BY *[Signature]*
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 REVISIONS
 NO. 1
 DATE
 BY
 DESCRIPTION



- Figure 10. - Concrete placement in 1:5 scale model.