Memorandum

Denver, Colorado
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Chief, Dams Branch
Attention: R.W. Whinnerah

Chief, Engineering Laboratories

Model tests to determine back pressures on relief drain outlets

Underdrains which are installed to prevent or reduce the hydrostatic or uplift pressure under a concrete floor or apron in connection with spillways sometimes terminate at a hood which is subjected to flowing water on the spillway face. It appeared possible under some operating conditions that the pressure on the downstream face of the relief drain outlet hood might be higher than the hydrostatic pressure under the slab. If this were the case, a check or flap gate would be needed on the outlet to obviate the possibility of water running into the drain and under the slab. Model tests were made to determine pressures on the downstream face of relief drains for various exit and hood designs under various flow conditions to see whether or not this condition would exist.

A 1:20 scale model of a Kirwin Dam type relief drain was installed in a tilting flume in which the chute could be adjusted from slopes of S = 0 to S = 0.133 (Figure 1). A control gate at the chute entrance permitted the flow depth and velocity to be varied. A pitot tube was used to measure the velocity at the underdrain. A piezometer opening on the downstream face of the drain hood was used to measure the pressure head; the drain was not permitted to discharge.

Two relationships were found to exist:

(a) For the same velocity and depth, the pressure on the face of the drain hood was the same for any floor slope.

(b) For a constant velocity but with varying water depth, the difference between the drain pressure and the depth at the hood was a constant.

A 1:10 scale model was installed and tested in the same setting as the 1:20 model. Since the larger model verified the results obtained with the smaller hood, the tests were continued to determine the relationship between floor slope, velocity, stream depth, and pressure on the downstream face of the hood for all conditions within the limitations of the model.

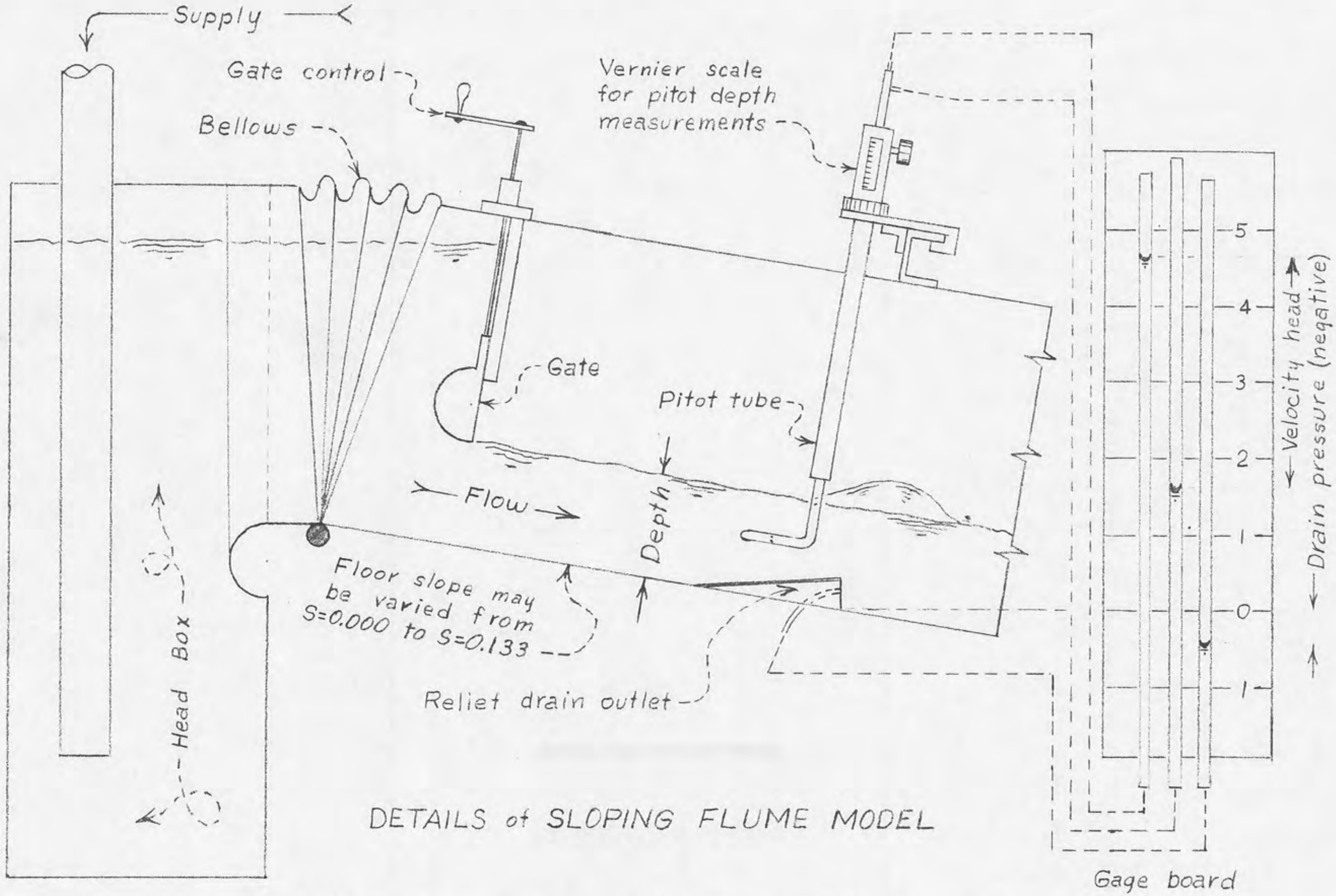
To reduce the data to usable form, a curve was drawn through the plotted points of velocity versus the depth of water necessary to maintain zero pressure on the downstream face of the drain hood (Figure 2). From this curve it is possible to determine the pressure on the drain for any known combination of velocity and depth since the difference between the pressure and the depth is a constant for a given velocity. If the computed field conditions of velocity and stream depth be plotted on the graph, the pressure on the hood will be the difference between the plotted point and the zero pressure curve for that velocity. (See examples 1 and 2, Figure 2).

A 1:10 scale model of a Tiber Dam type relief drain hood was installed in the flume and tested in the same manner as for the Kirwin type. The curve, velocity versus depth for zero pressure for this drain hood, is shown on Figure 3. A photograph of the pitot tube and the Tiber relief drain model is shown on Figure 6B.

These velocity versus depth curves are valid only above some minimum depth. A test was made using the Tiber drain with a thin sheet of water flowing down the spillway, and with a floor slope of S = 0.110. As the water surface was lowered and the depth of the stream approached the height of the drain, a hump formed on the water surface keeping the downstream face of the drain submerged. It was found that the curve was valid for the Tiber Dam drain hood for all flow depths greater than 0.55-foot (prototype). For depths less than this, the sheet of water parted at the upper corners of the drain hood and an air pocket extended downstream from the drain outlet. The jet passing over the drain hood and striking the floor of the spillway caused the water to back up until it stood about 0.13-foot (prototype) deep on the face of the hood.

During tests on the Alamogordo spillway, two underdrain hood shapes were suggested for installation on the spillway face, (Figure 6A). These were tested and evaluated to arrive at the same type of curve obtained for the Tiber and Kirwin drains. Since the Alamogordo drains were installed at the point of minimum pressure on the parabolic curve downstream from the spillway gates, the pressure head rather than the depth was used in the computations. The shape and installation of the drains and the velocity and depth curves are shown on Figures 4 and 5.

Attachments



BACK PRESSURES on RELIEF DRAIN OUTLETS

FIGURE 1

4-21-55 Colgate

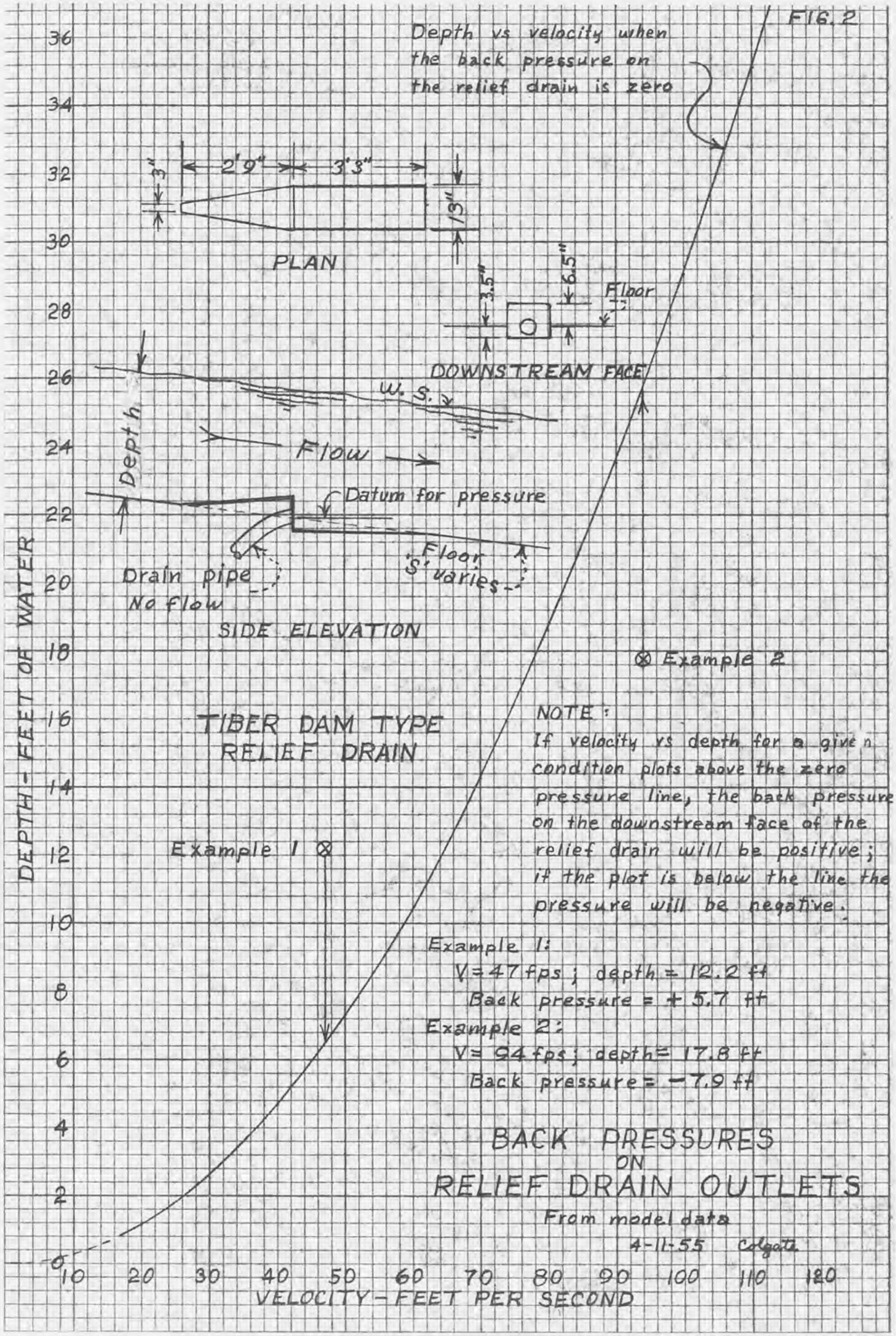


FIG. 2
Depth vs velocity when the back pressure on the relief drain is zero
2'9"
3'3"
3"
13"
PLAN
3.5"
6.5"
Floor
DOWNSTREAM FACE
W. S.
Depth h
Flow
Datum for pressure
Floor
'S' varies
Drain pipe
No flow
SIDE ELEVATION
TIBER DAM TYPE
RELIEF DRAIN
Example 1
Example 2
NOTE:
If velocity vs depth for a given condition plots above the zero pressure line, the back pressure on the downstream face of the relief drain will be positive; if the plot is below the line the pressure will be negative.
Example 1:
V = 47 fps; depth = 12.2 ft
Back pressure = + 5.7 ft
Example 2:
V = 94 fps; depth = 17.8 ft
Back pressure = − 7.9 ft
BACK PRESSURES
ON
RELIEF DRAIN OUTLETS
From model data
4-11-55 Colgate
DEPTH - FEET OF WATER
VELOCITY - FEET PER SECOND
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
10
20
30
40
50
60
70
80
90
100
110
120

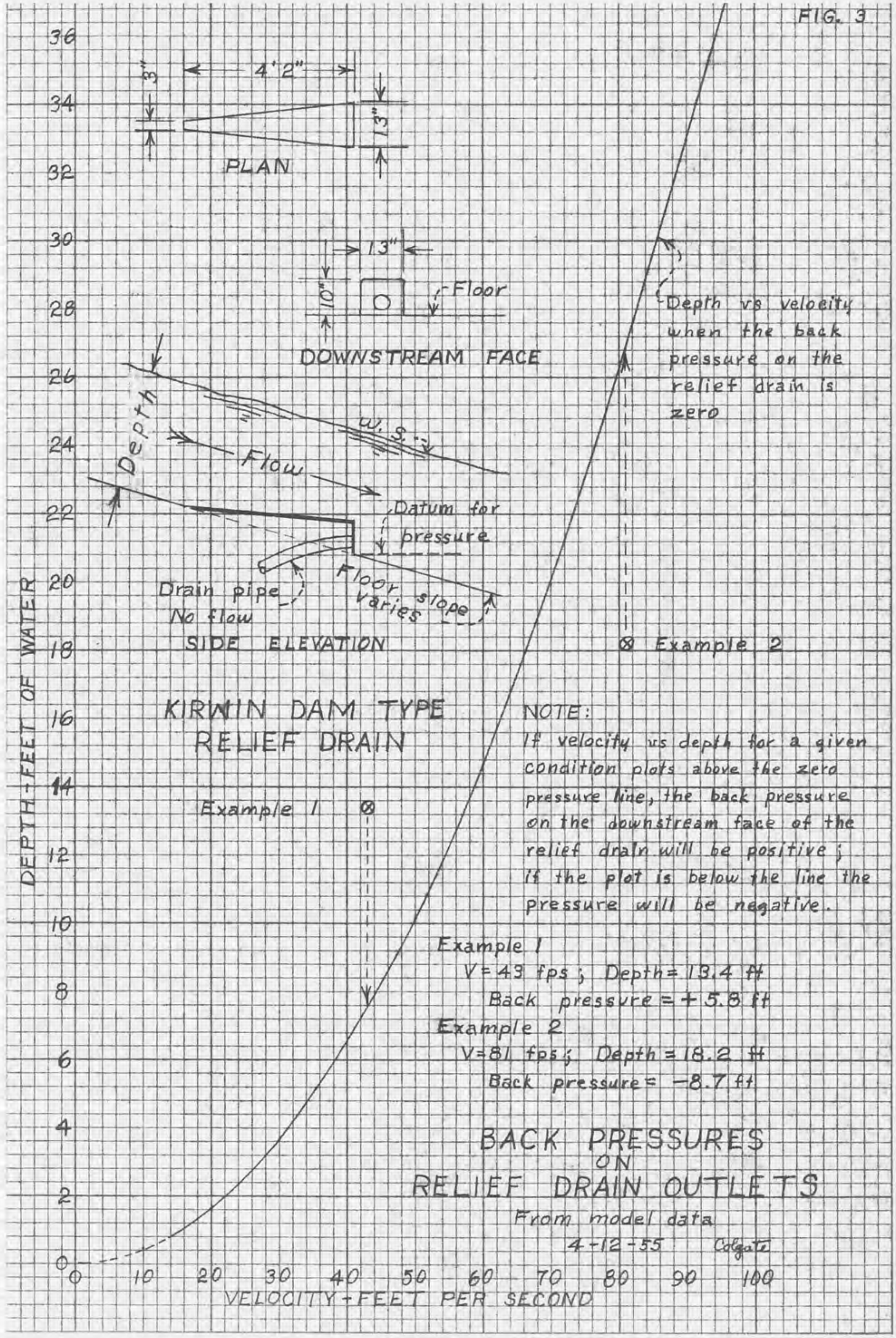


FIG. 3
PLAN
4'2"
3"
13"
13"
10"
Floor
DOWNSTREAM FACE
Depth
Flow
W. S.
Datum for pressure
Drain pipe
No flow
Floor slope varies
SIDE ELEVATION
KIRWIN DAM TYPE RELIEF DRAIN
Example 1
Depth vs velocity when the back pressure on the relief drain is zero
Example 2
NOTE:
If velocity vs depth for a given condition plots above the zero pressure line, the back pressure on the downstream face of the relief drain will be positive; if the plot is below the line the pressure will be negative.
Example 1
V = 43 fps; Depth = 13.4 ft
Back pressure = + 5.8 ft
Example 2
V = 81 fps; Depth = 18.2 ft
Back pressure = −8.7 ft
BACK PRESSURES ON RELIEF DRAIN OUTLETS
From model data
4-12-55 Colgate
DEPTH - FEET OF WATER
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
VELOCITY - FEET PER SECOND
0
10
20
30
40
50
60
70
80
90
100

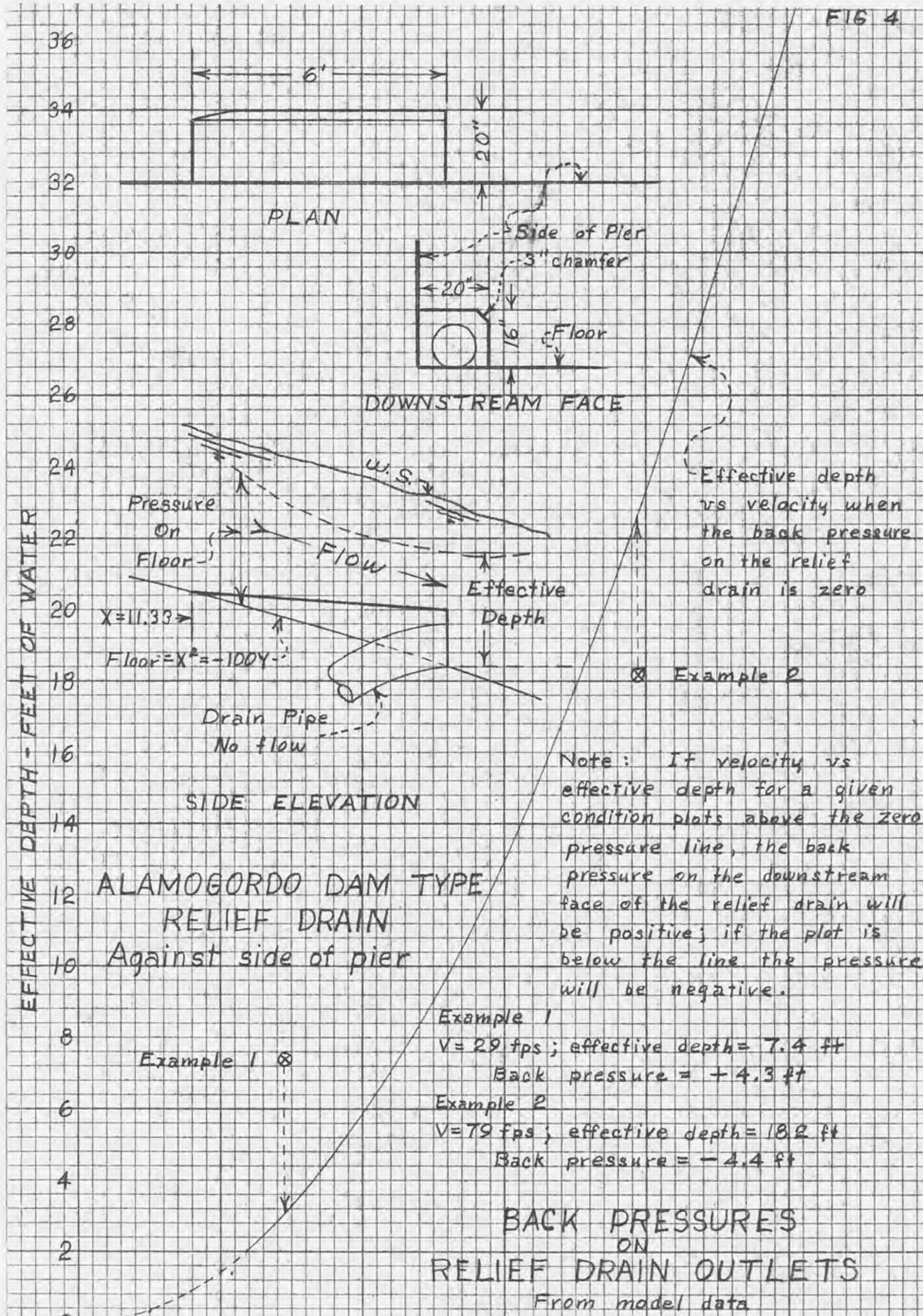


FIG 4
EFFECTIVE DEPTH - FEET OF WATER
VELOCITY - FEET PER SECOND
0 10 20 30 40 50 60 70 80 90 100
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
6'
20"
PLAN
Side of Pier
3" chamfer
20"
16"
Floor
DOWNSTREAM FACE
W.S.
Pressure On Floor
Flow
Effective Depth
X=11.33
Floor=X²=-100Y
Drain Pipe No flow
SIDE ELEVATION
Effective depth vs velocity when the back pressure on the relief drain is zero
Example 2
Note: If velocity vs effective depth for a given condition plots above the zero pressure line, the back pressure on the downstream face of the relief drain will be positive; if the plot is below the line the pressure will be negative.
ALAMOGORDO DAM TYPE
RELIEF DRAIN
Against side of pier
Example 1
Example 1
V= 29 fps; effective depth= 7.4 ft
Back pressure = +4.3 ft
Example 2
V=79 fps; effective depth= 18.2 ft
Back pressure = −4.4 ft
BACK PRESSURES
ON
RELIEF DRAIN OUTLETS
From model data
4-15-55 Colgate

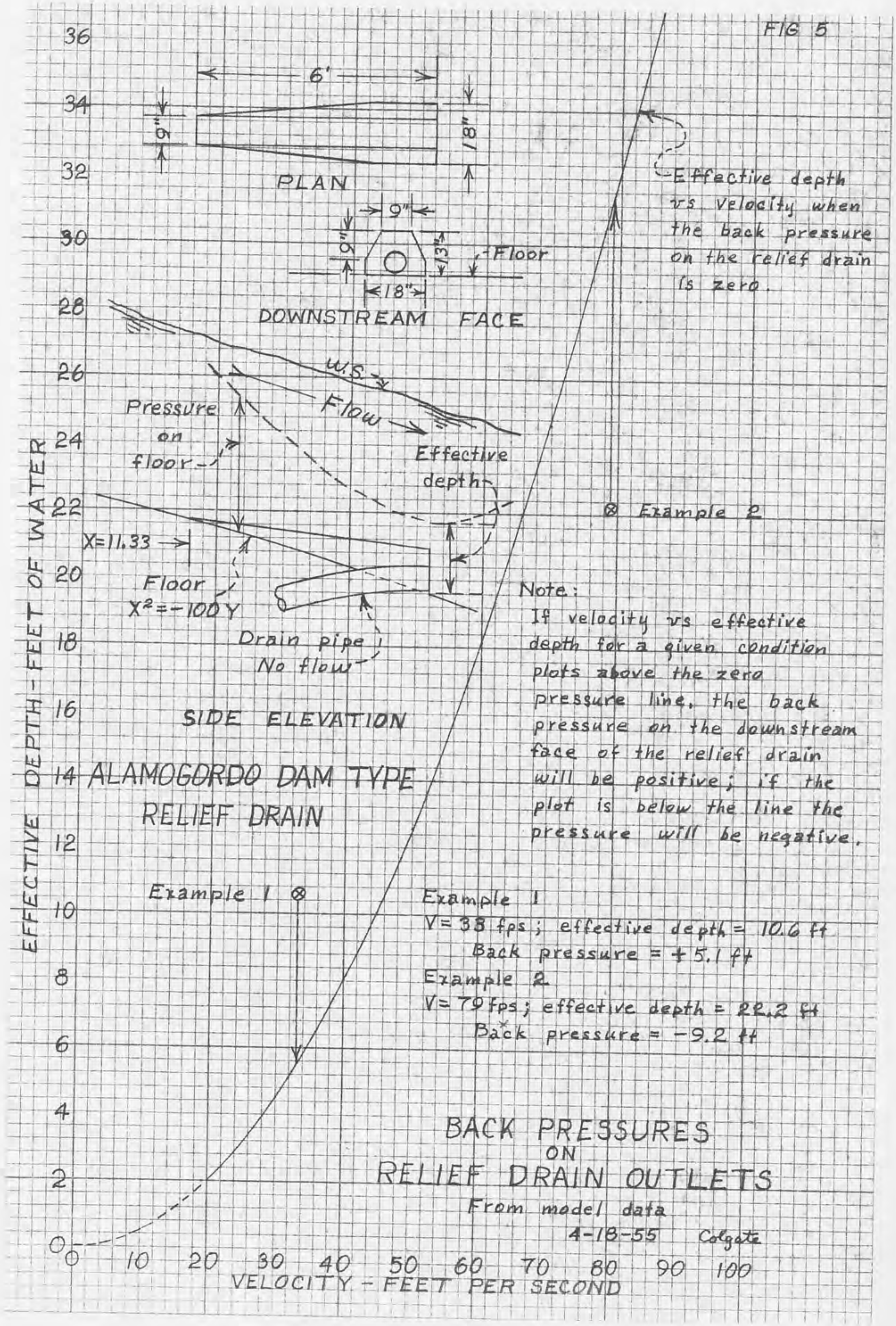
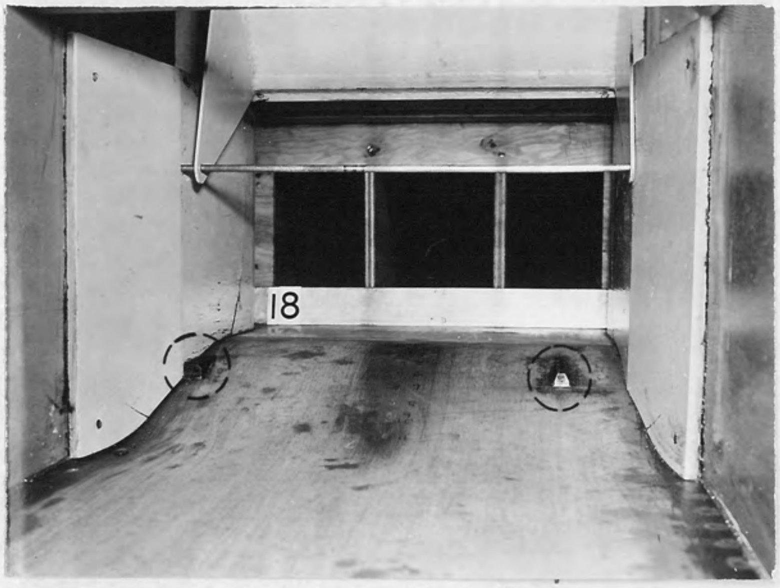


FIG 5
6'
9"
18"
PLAN
9"
9"
13"
Floor
18"
DOWNSTREAM FACE
W.S.
Flow
Pressure on floor
Effective depth
X=11.33
Floor
X²=-100Y
Drain pipe
No flow
SIDE ELEVATION
ALAMOGORDO DAM TYPE
RELIEF DRAIN
Effective depth vs velocity when the back pressure on the relief drain is zero.
Example 2
Note:
If velocity vs effective depth for a given condition plots above the zero pressure line, the back pressure on the downstream face of the relief drain will be positive; if the plot is below the line the pressure will be negative.
Example 1
Example 1
V= 38 fps; effective depth = 10.6 ft
Back pressure = +5.1 ft
Example 2
V= 79 fps; effective depth = 22.2 ft
Back pressure = -9.2 ft
BACK PRESSURES
ON
RELIEF DRAIN OUTLETS
From model data
4-18-55
Colgate
EFFECTIVE DEPTH - FEET OF WATER
VELOCITY - FEET PER SECOND
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
0
10
20
30
40
50
60
70
80
90
100



A. Alamogordo Dam, 1:36 Scale Model, Showing One Underdrain Outlet Against The Side Of The Pier And Another In The Chute.

B. Tiber Dam Type Relief Drain Outlet And Pitot Tube.

BACK PRESSURES ON RELIEF DRAIN OUTLETS