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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 169

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SHAPE OF OVERFALL SECTION FOR DAVIS DAM SPILLWAY DAVIS DAM PROJECT

By

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Denver, Colorado
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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
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Laboratory Report No. 169
Hydraulic Laboratory

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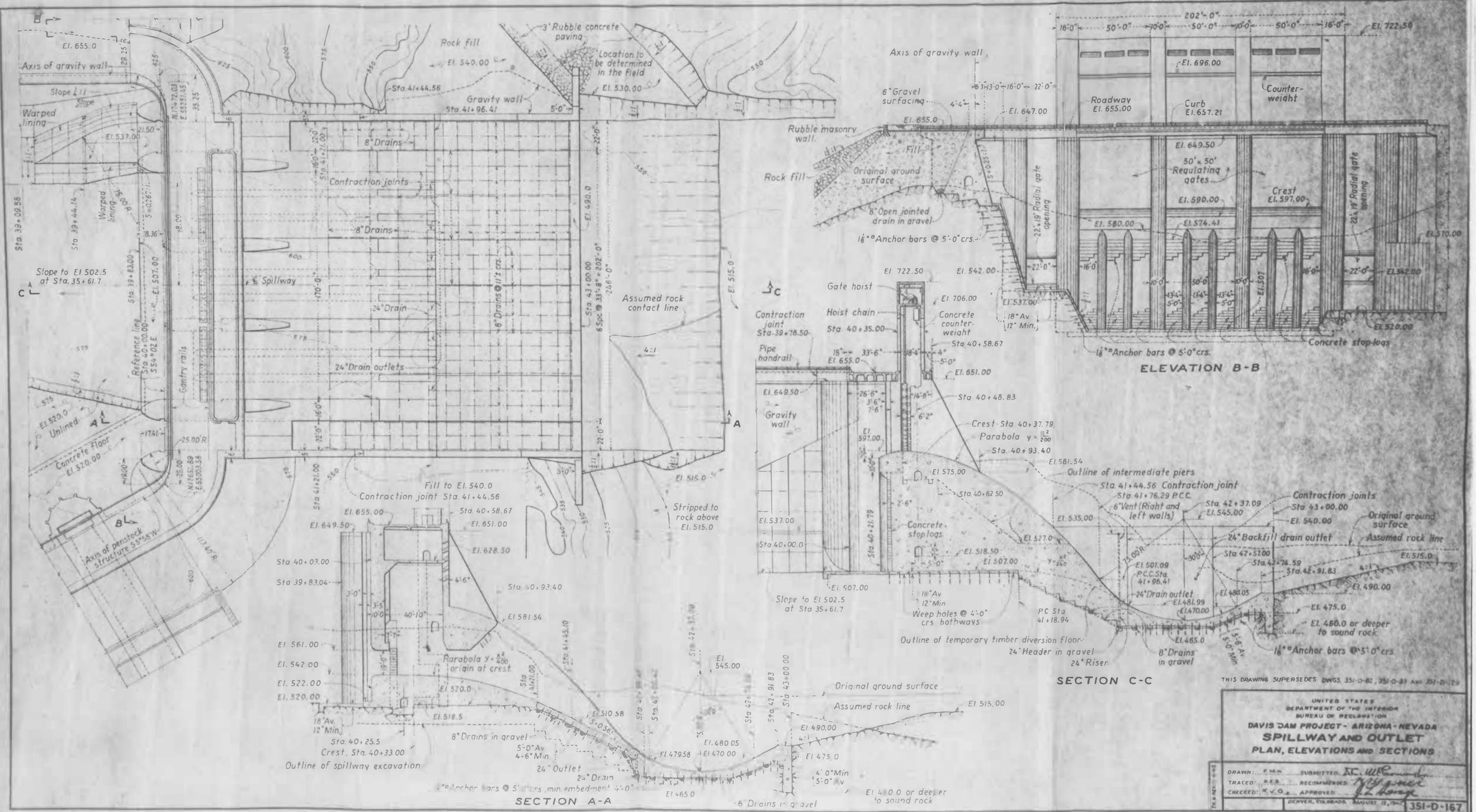
Reviewed by: J. E. Warnock

Subject: Shape of overfall section for Davis Dam spillway - Davis Dam Project.

1. Purpose of investigation. The original design of the overfall section for the spillway at Davis Dam, figure 1, was proportioned in the following manner. The section from the upstream face of the dam to the crest was designed to fit the shape of the lower surface of the sheet of water flowing over it for the gate completely open and a 58-foot head on the crest. The portion from the crest to the beginning of the reverse curve in the spillway bucket was proportioned to fit the theoretical trajectory of a sheet of water issuing from a 1-foot gate opening produced by a head of 50 feet on the crest. This has been the customary method of designing overfall shapes with radial or slide gates on the crest. The principal consideration in this case has been to proportion the shape of the overfall section to fit the shape of the under side of the overfalling sheet of water for the most adverse condition of operation. This will result in the most economical as well as the most efficient shape of section on which subatmospheric pressures will be extremely small or nonexistent. There are in existence, dams on which the spillway section falls inside the profile outlined by the under shape of the overfalling sheet of water for the maximum discharge condition. Where aeration under the sheet of water is difficult to obtain, fluctuating pressures under the nappe are often the result.*[1] When a negative pressure occurs under the nappe there is a tendency for the sheet of water to be forced down against the face of

*[1] References to the vibration of the sheet of water flowing over dams are contained in the bibliography at the conclusion of this report.



THIS DRAWING SUPERSEDES DWGS. 351-D-82, 351-D-83 AND 351-D-129

UNITED STATES
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DAVIS DAM PROJECT - ARIZONA - NEVADA

SPILLWAY AND OUTLET
PLAN, ELEVATIONS AND SECTIONS

DRAWN: F.M.H. SUBMITTED:
TRACED: R.E.B. RECOMMENDED:
CHECKED: K.V.O. APPROVED:
DENVER, COLORADO, AUGUST 12, 19

351-D-167

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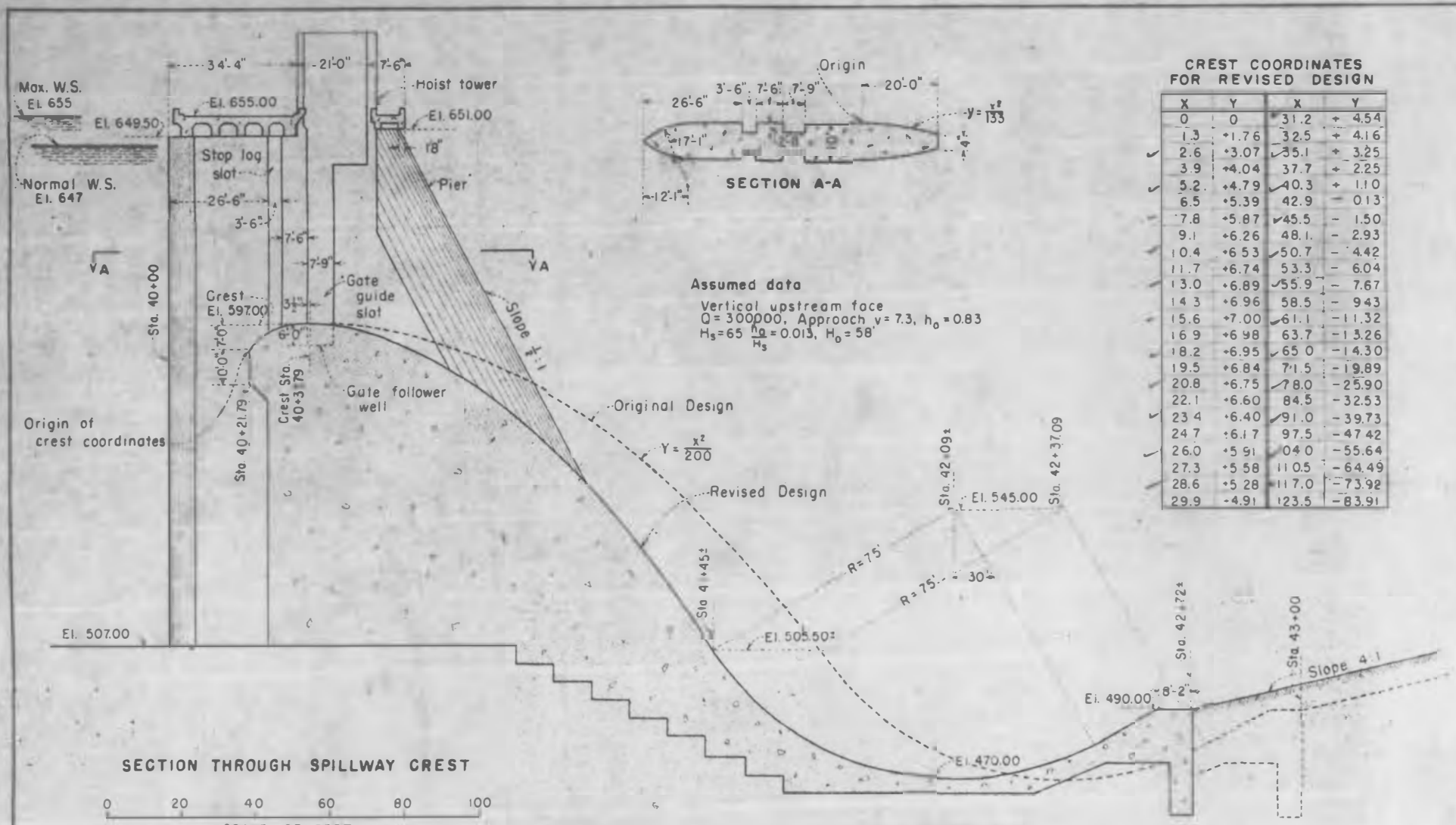
the spillway section. As this pressure reaches a sufficiently negative value, partial temporary relief is obtained by air either penetrating through the sheet of water or by air extracted from the water as the pressure under the sheet approaches the vapor pressure of water. The result is continually changing pressures, resulting in fluctuations of the overfalling sheet of water for the greater discharge conditions. In some cases this fluctuation has initiated audible pressure waves in the atmosphere causing windows to rattle and other property in the vicinity of the dam to oscillate with sometimes weird effects. Experience has shown that fluctuation of the sheet of water ordinarily produces no particular material damage to the spillway on which it occurs; however, it is clearly evident that the sensory effects produced by this condition are not conducive to a healthy state of mind for people living downstream from the dam. For this reason, primarily, it has been customary in the Bureau of Reclamation to design spillway shapes to either fit the lower nappe shape of the jet or project outside of this profile for maximum flow conditions, thus avoiding negative pressures.

Tests on the Davis Dam spillway were made for the purpose of investigating pressures on the spillway face when the profile of the overflow section falls inside the trajectory of the sheet of water flowing over it. In the latter case the overflow section was proportioned from the material in the "Abstract of Studies of Crests For Overfall Dams, bulletin 3, part VI of Boulder Canyon Final Reports," by J. N. Bradley, HYD-122. The entire overflow section was designed to fit the shape of the lower nappe of the sheet of water flowing over it for the gate completely raised with 58 feet of head on the crest. In this case negative pressures can be expected at the smaller gate openings. A comparison of the profiles of the original and the revised overflow sections for the Davis Dam spillway is shown on figure 2. The revised design represents a large saving in concrete.

2. The model. Investigation of the pressures on the face of the revised spillway was made by the aid of a model constructed on a 1:50 scale. The model was fabricated accurately of sheet metal and installed in a rectangular flume 23 inches in width. A photograph of the model,



CREST COORDINATES FOR REVISED DESIGN

X	Y	X	Y
0	0	31.2	+ 4.54
1.3	+1.76	32.5	+ 4.16
2.6	+3.07	35.1	+ 3.25
3.9	+4.04	37.7	+ 2.25
5.2	+4.79	40.3	+ 1.10
6.5	+5.39	42.9	− 0.13
7.8	+5.87	45.5	− 1.50
9.1	+6.26	48.1	− 2.93
10.4	+6.53	50.7	− 4.42
11.7	+6.74	53.3	− 6.04
13.0	+6.89	55.9	− 7.67
14.3	+6.96	58.5	− 9.43
15.6	+7.00	61.1	−11.32
16.9	+6.98	63.7	−13.26
18.2	+6.95	65.0	−14.30
19.5	+6.84	71.5	−19.89
20.8	+6.75	78.0	−25.90
22.1	+6.60	84.5	−32.53
23.4	+6.40	91.0	−39.73
24.7	+6.17	97.5	−47.42
26.0	+5.91	104.0	−55.64
27.3	+5.58	110.5	−64.49
28.6	+5.28	117.0	−73.92
29.9	−4.91	123.5	−83.91

DAVIS DAM

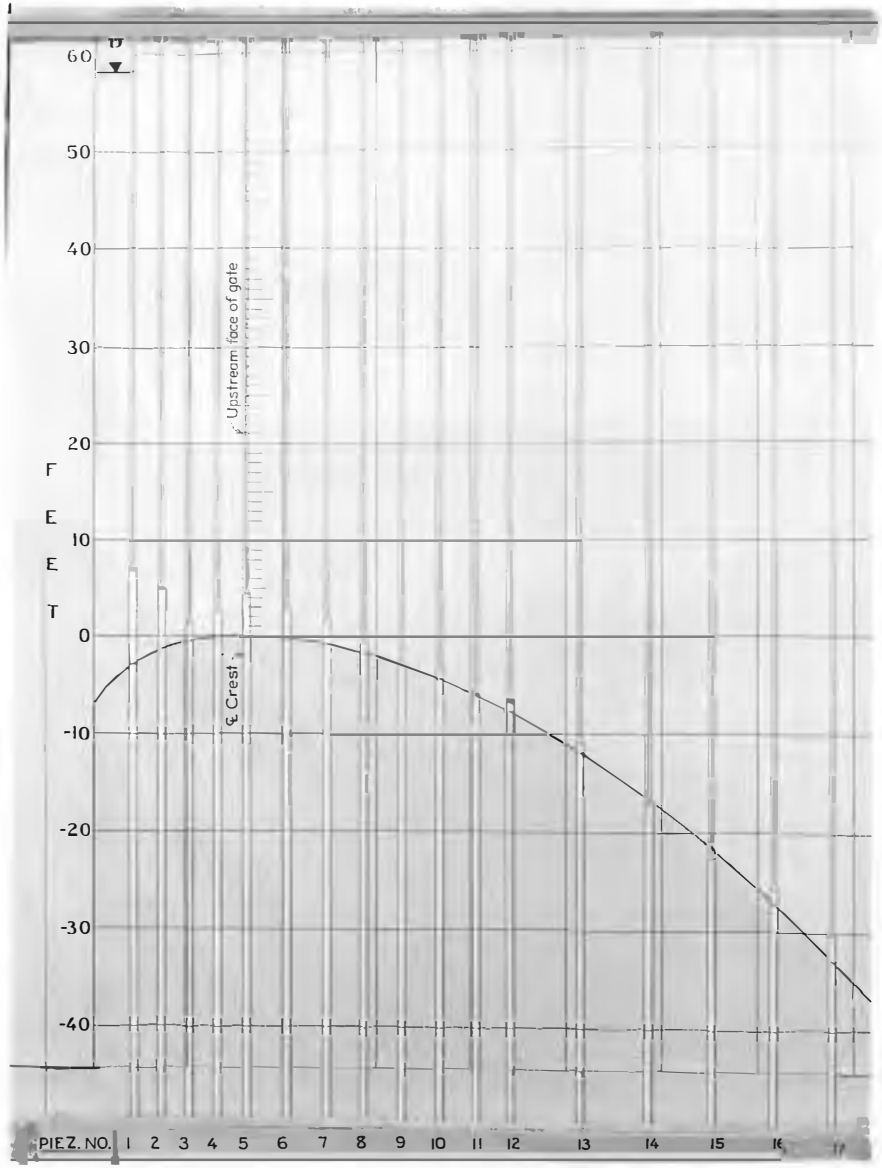
COMPARISON OF SPILLWAY PROFILES OF ORIGINAL AND REVISED DESIGNS

FIGURE - 2

looking upstream, is shown on figure 3A. A half pier was installed on each side of the flume thus the crest length represented 88 feet, prototype. Actually, the Davis Dam spillway will have 3 gates measuring 50 by 50 feet. Seventeen piezometers were installed along the face of the model and the pressures were registered by water manometers as shown in figure 3B. A profile of the spillway shape was drawn on the manometer board on a 1:50 scale and the results were recorded by photographs. Pressures above the line are positive, those below are negative. Pressures can be scaled from the photographs with an engineer's scale (1 inch = 20 feet). The gate position and the head under which the spillway was operating are shown on each of the following photographs. A few drops of an aerosol and fluorescein solution were placed in each of the small monometer tubes and connecting lines. The aerosol served to counteract surface tension and the fluorescein fluoresced in the presence of ultra-violet light producing a very distinct record on ordinary photographic film.

3. Pressure results. A series of tests was first made for various heads on the crest with the gate raised completely clear of the water. Photographs were taken of the manometer board for each head. As the overflow section was designed for a head of 58 feet, the first run was made for this condition and the pressures are shown on figure 3B. Actually all of the pressures for this run should read zero as the revised overflow section, shown on figure 2, was designed for this condition as a criterion. This means that the water surfaces in the manometer tubes should fall along the profile line on the manometer board. The results are within experimental error and seldom is the agreement between the design data and the model results better than that shown on figure 3B. The variations in pressure are due principally to inaccuracies in installing the piezometers in the model. These are difficult to control on a surface of this shape. Some of the pressures are zero, some positive, and a few slightly negative. Figures 4 to 7, inclusive, show pressures on the overflow face, with the gate out of water, for heads of 50, 40, 30, 25, 20, 15, 10, and 5 feet on the crest. These runs were made as a matter of record for future reference.

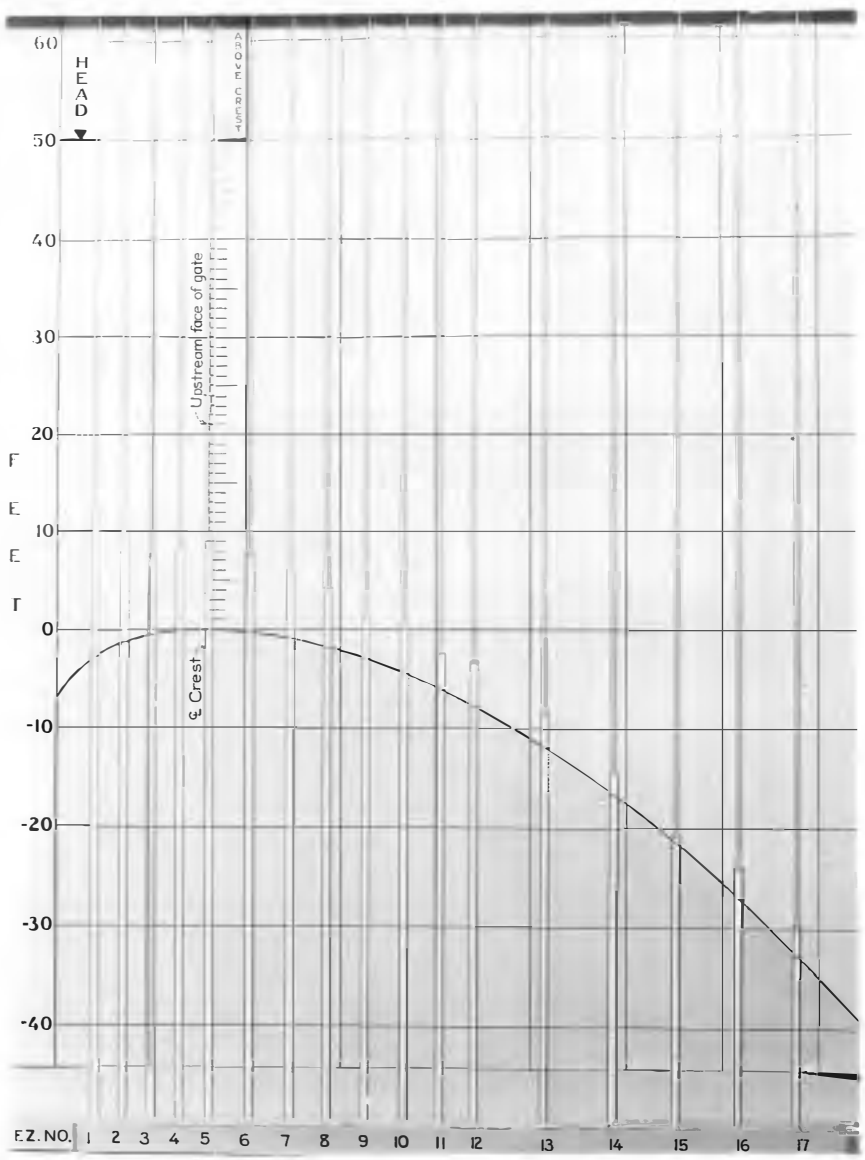
A - Model of section of Davis Dam on 1:50 scale- View looking upstream



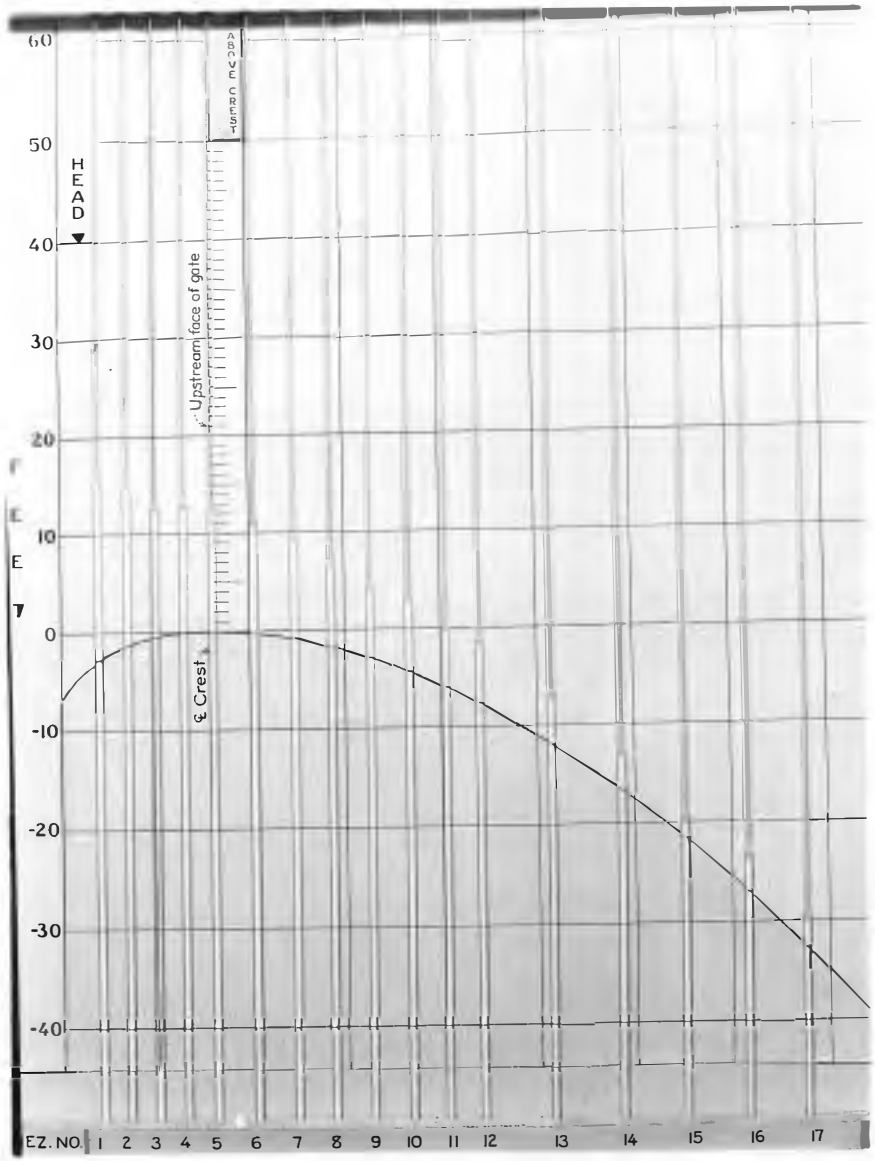
B - Pressures on overfall face at the designed head (58 feet above crest)

DAVIS DAM SPILLWAY MODEL

FIGURE 3



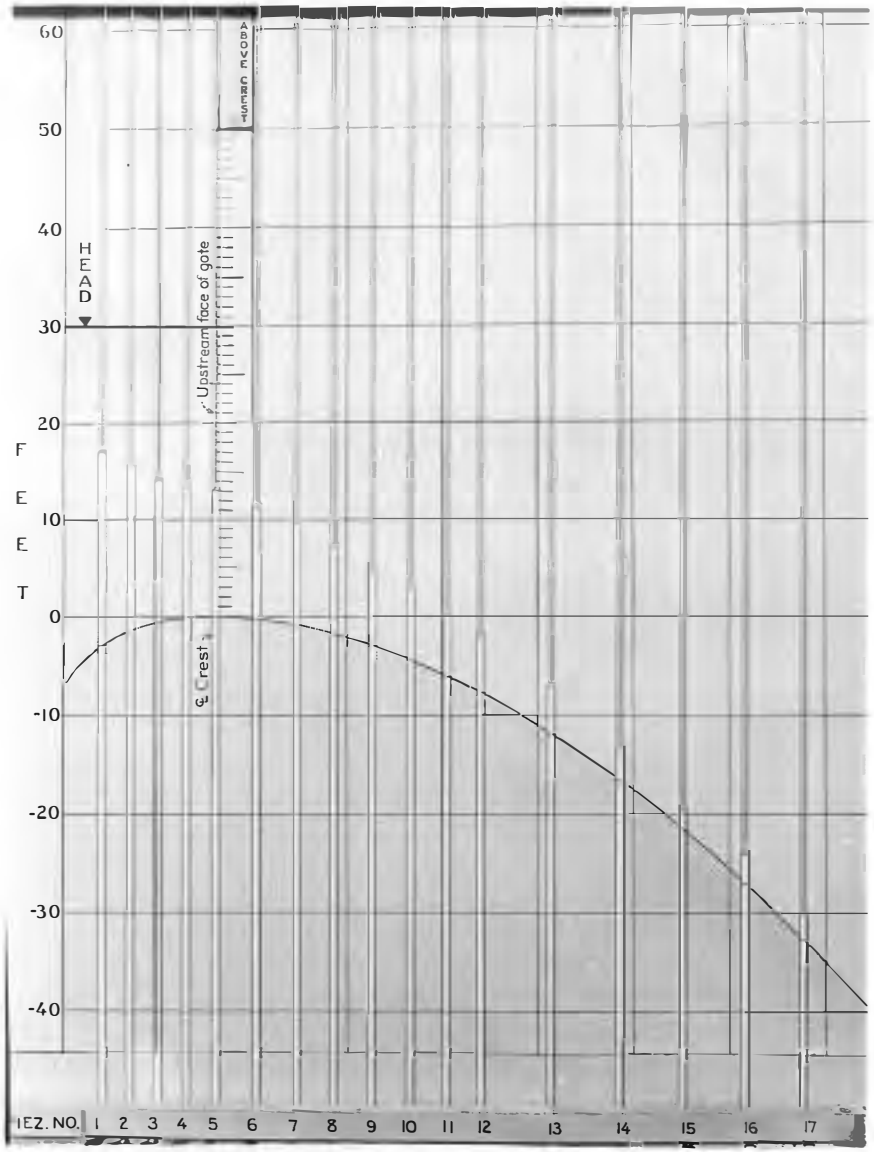
A - Head of fifty feet on crest



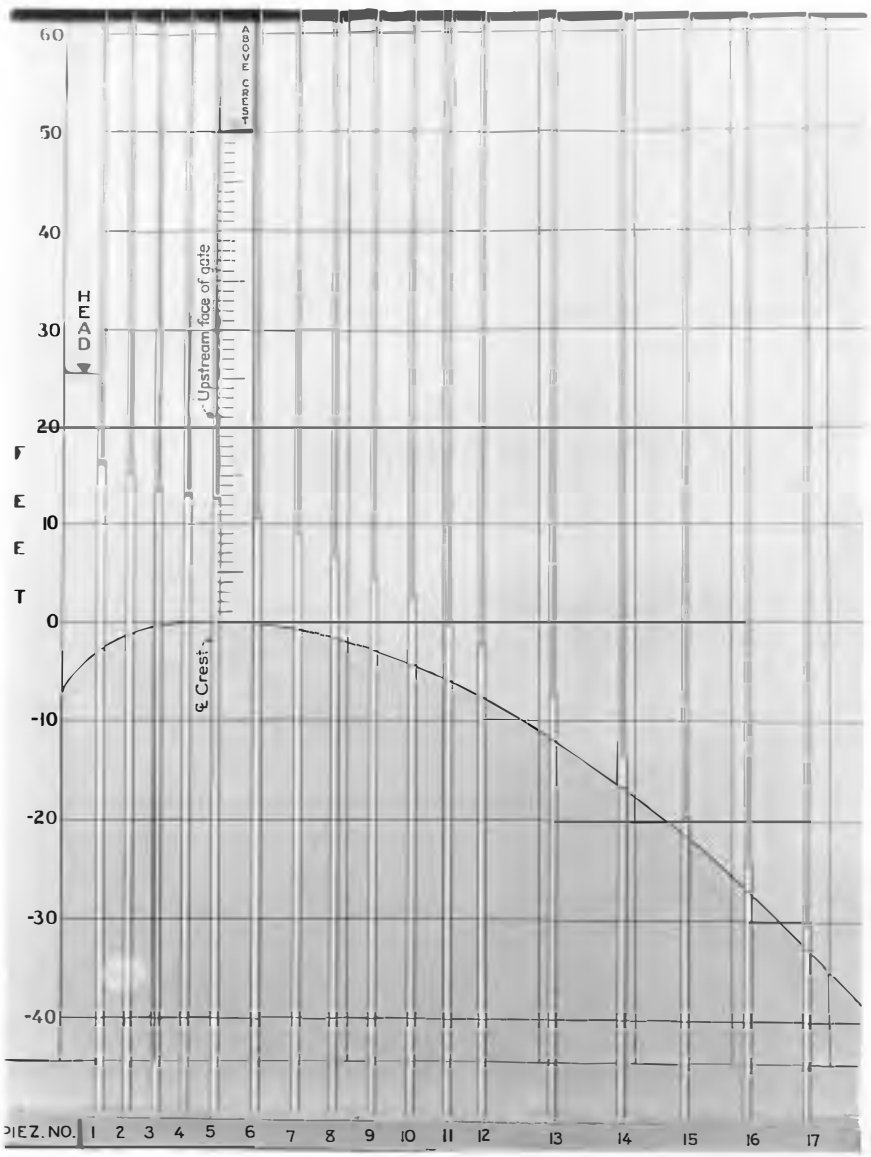
B - Head of forty feet on crest

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - GATE FULLY OPEN

FIGURE 4



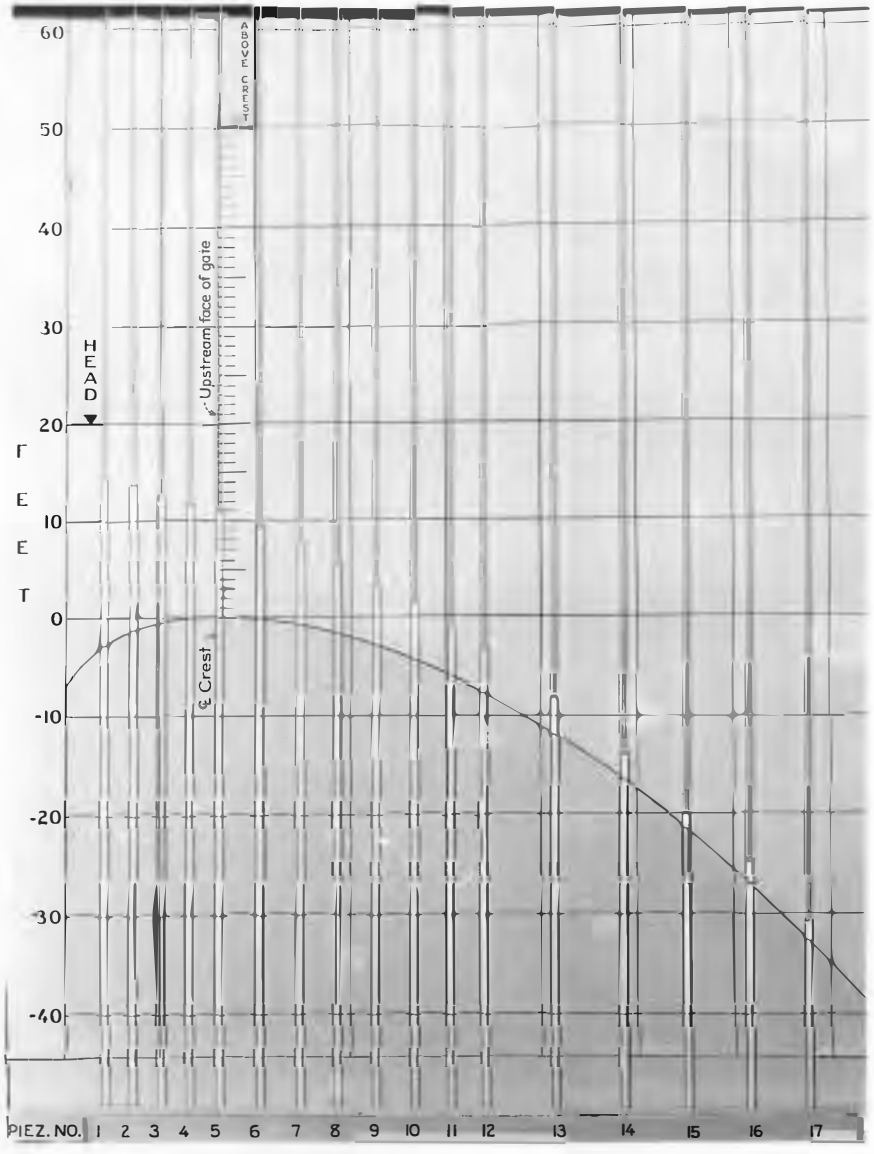
A - Head of thirty feet on crest



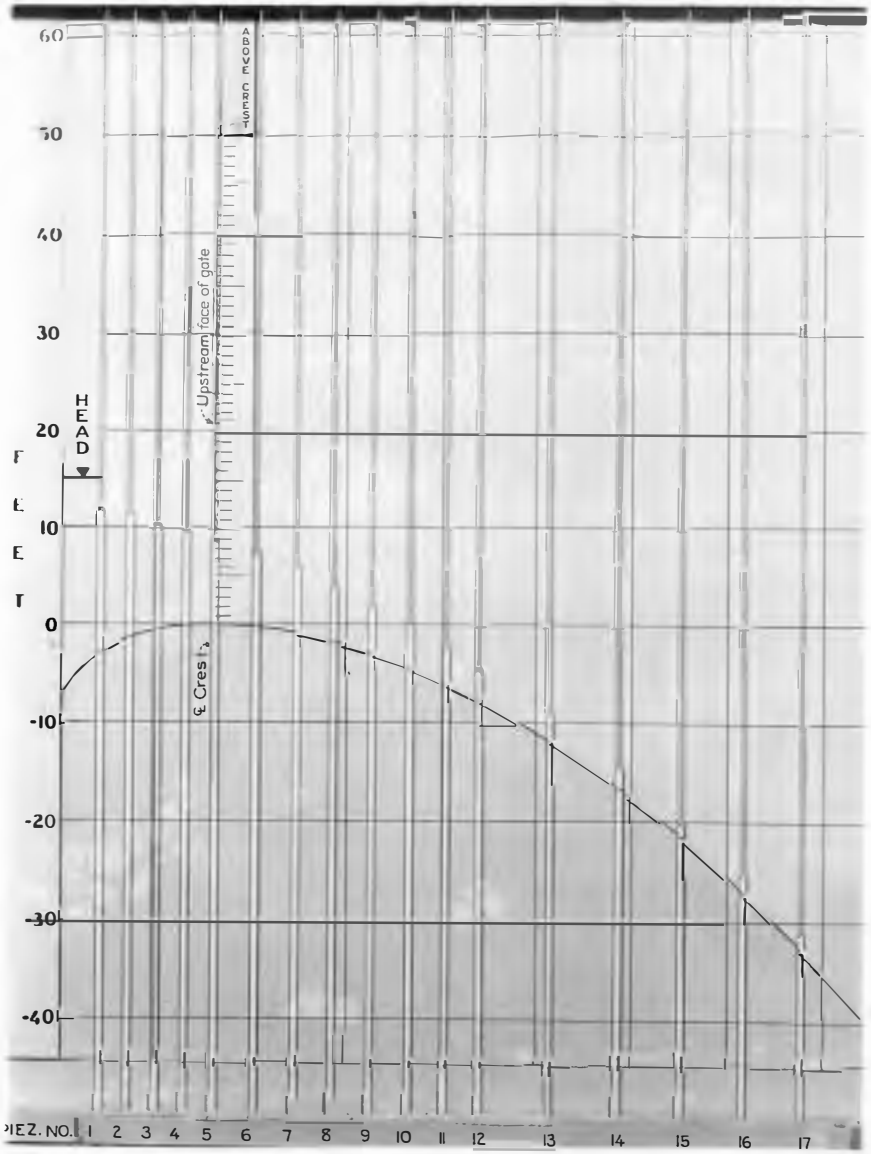
B - Head of twenty-five feet on crest

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - GATE FULLY OPEN

FIGURE 9



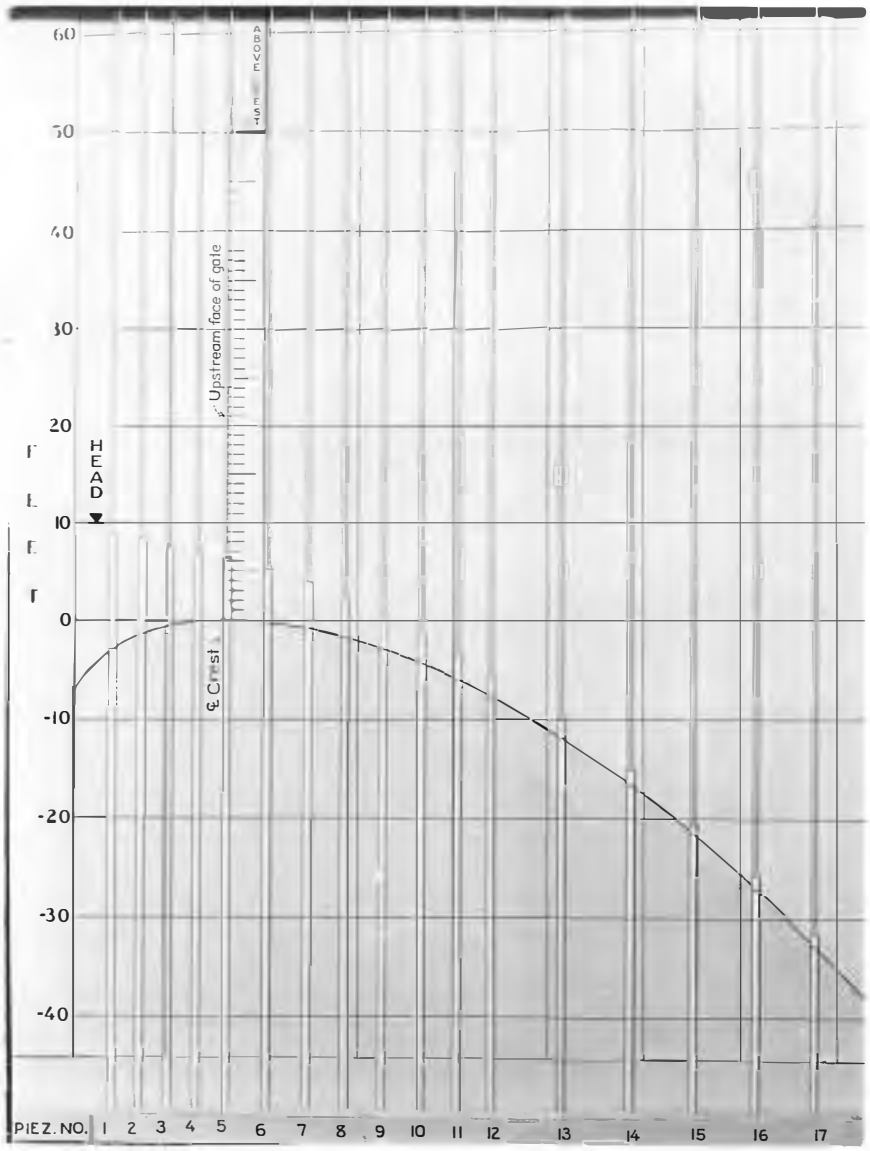
A - Head of twenty feet on crest



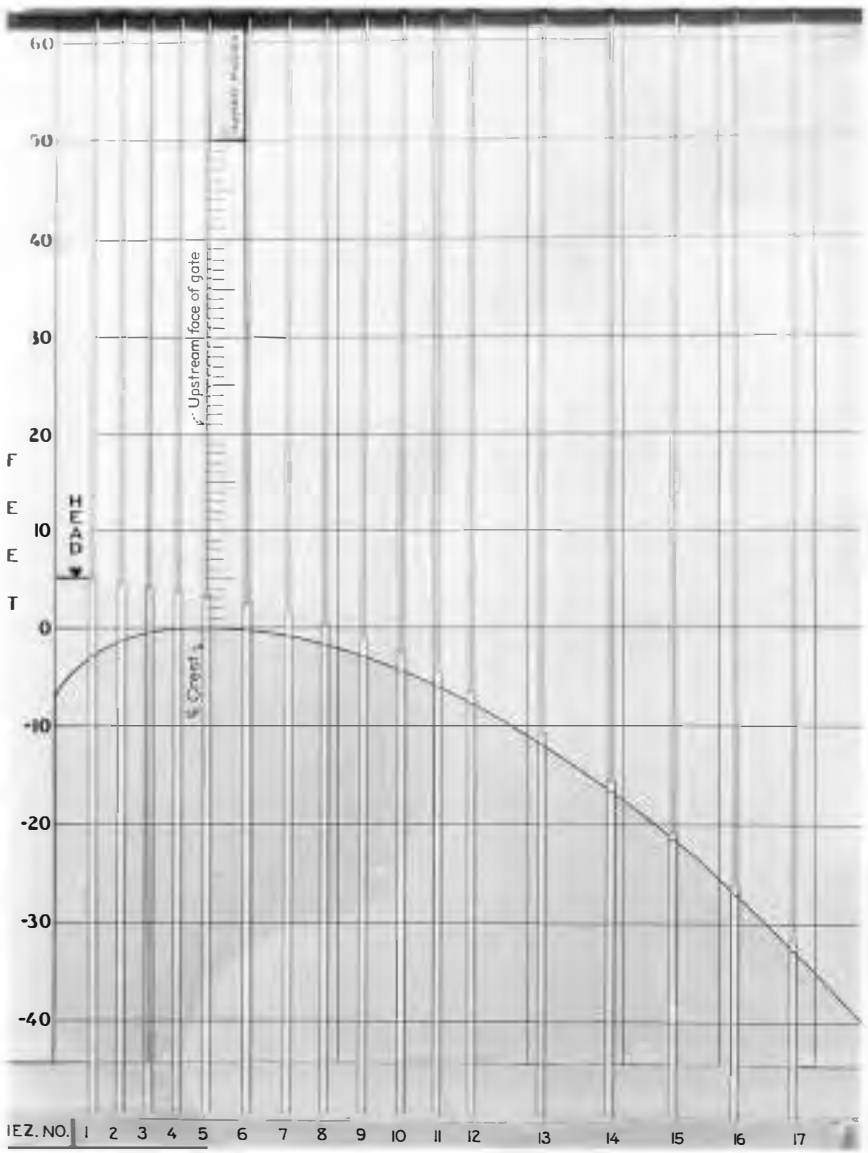
B - Head of fifteen feet on crest

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - GATE FULLY OPEN

FIGURE 9



A - Head of ten feet on crest



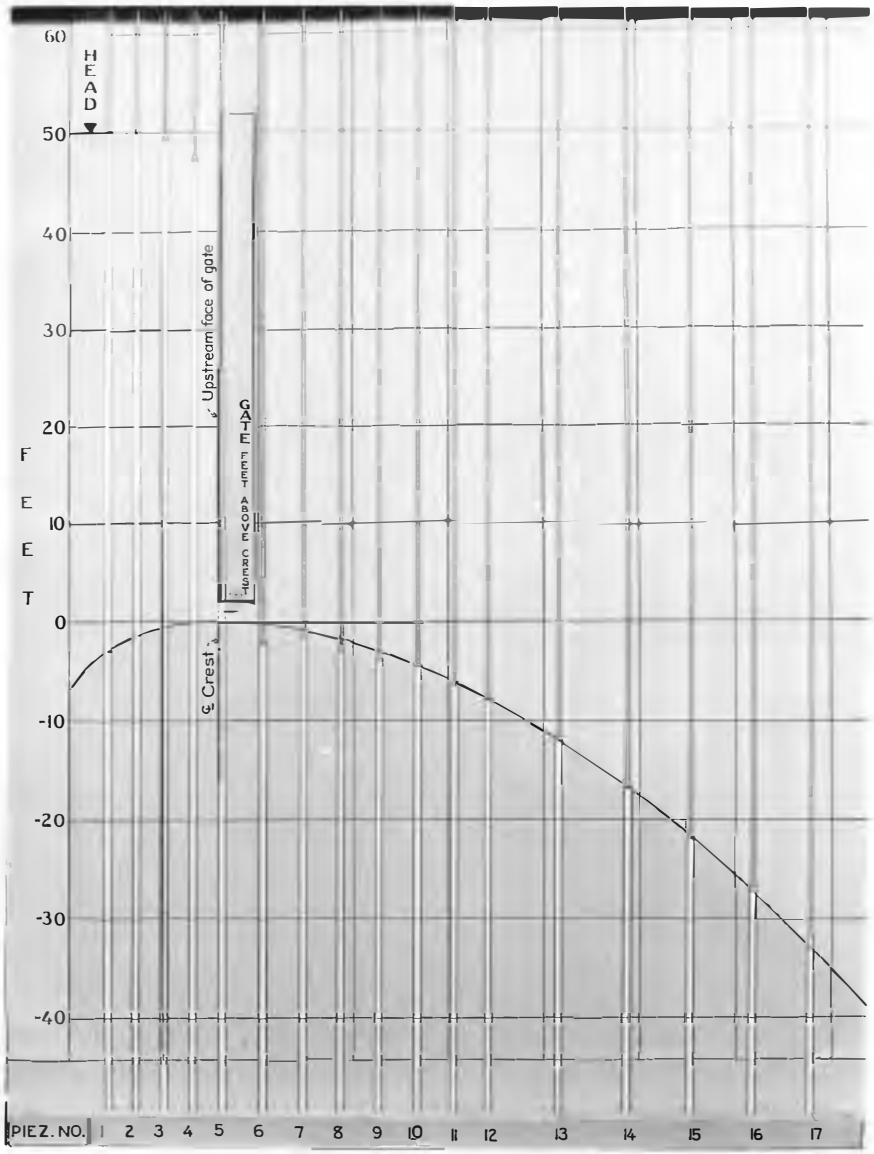
B - Head of five feet on crest

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - GATE FULLY OPEN

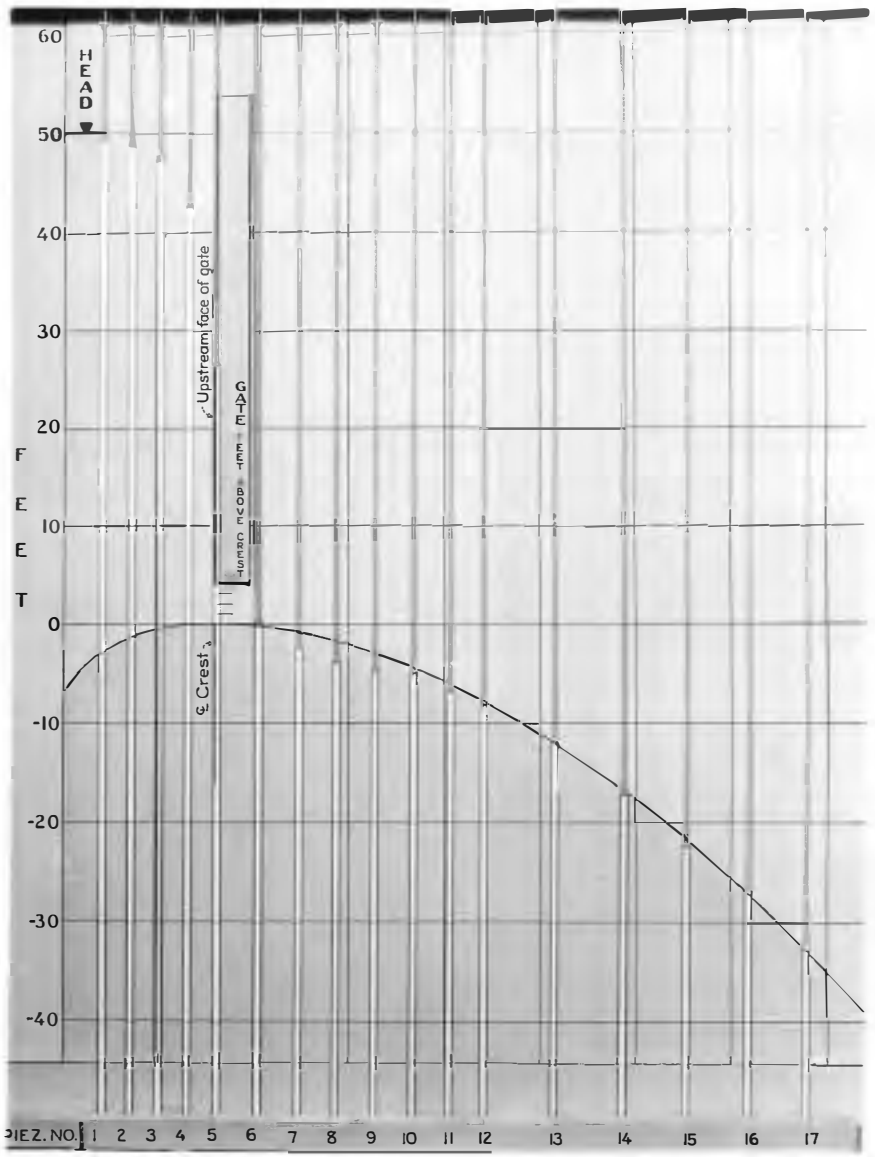
FIGURE 7

A second series of tests was made for various gate openings while holding the head on the crest at 50 feet. A record of the pressures on the overflow face for gate openings of 2, 4, 6, 8, 10, 12, 14, 16, 20, and 30 feet is shown in figures 8 to 12, inclusive. It was not possible to obtain a satisfactory record of the pressures for a 40-foot gate opening at a head of 50 feet as this was approaching free flow or the point at which the water surface sprang free from the bottom of the gate. The negative pressures were quite small for even the most severe operating condition. The maximum negative pressure recorded was 3 feet of water, prototype, which occurred at piezometers 8 and 9 for several gate openings ranging from 8 to 12 feet. This is not considered to be of sufficient magnitude to produce any noticeable effect on the operation of the spillway. In fact, these small negative pressures should keep the sheet of water continually depressed against the spillway face. They are not large enough to create relief or self-aeration in themselves. In as much as it is desired to explore the possibility of future use of overfall sections permitting negative pressures on the face, it appears that this design is sufficiently conservative for a beginning. The Davis Dam spillway, figure 1, is so designed that unobstructed aeration of the overfall face will be possible downstream from the piers. There is no provision between piers for aeration and negative pressures will be present in this region for the conditions of operation shown on figures 8 through 12.

4. Spillway calibration. As this model was of sufficient size for calibration purposes, a set of runs was made at various heads and gate openings. Calibration curves obtained from this data show the head plotted with respect to discharge for various positions of the gate on figure 13. The curves represent the discharge for one of three 50- by 50-foot gates. The dotted line paralleling the free-discharge curve indicates the head at which the flow changes from orifice flow to free discharge for a falling upstream reservoir surface. A coefficient of discharge curve is shown for free flow on the right of figure 13. The coefficient of discharge for the designed head of 58 feet is



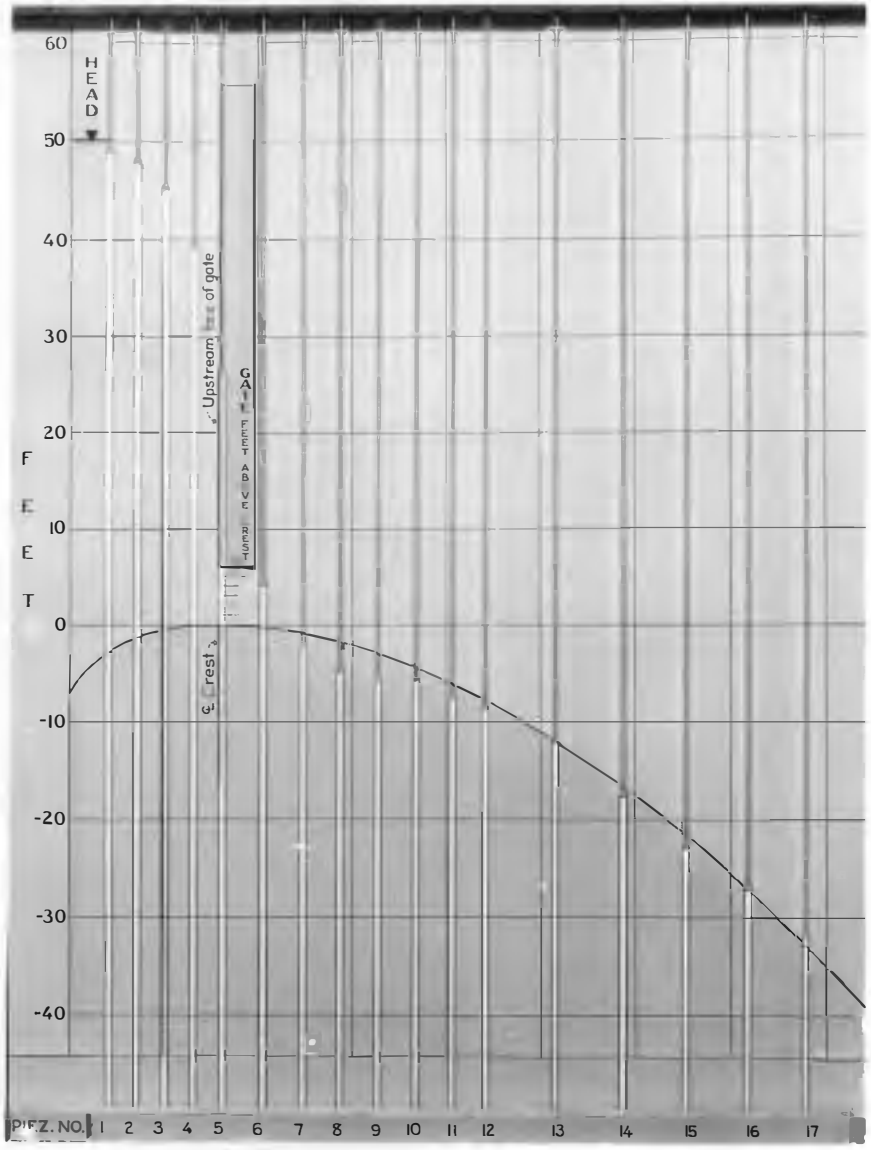
A - Gate opening two feet



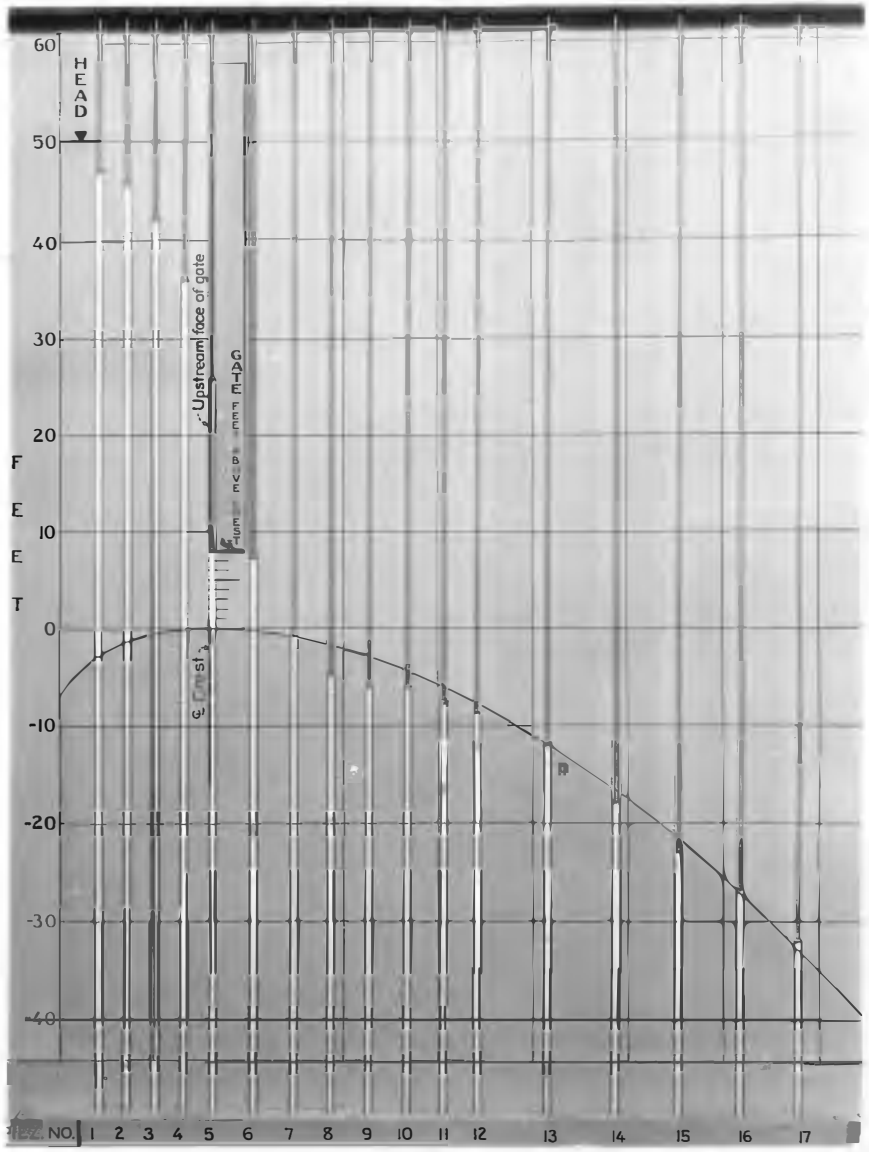
B - Gate opening of four feet

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - FOR 50 FEET OF HEAD ON CREST

FIGURE 8



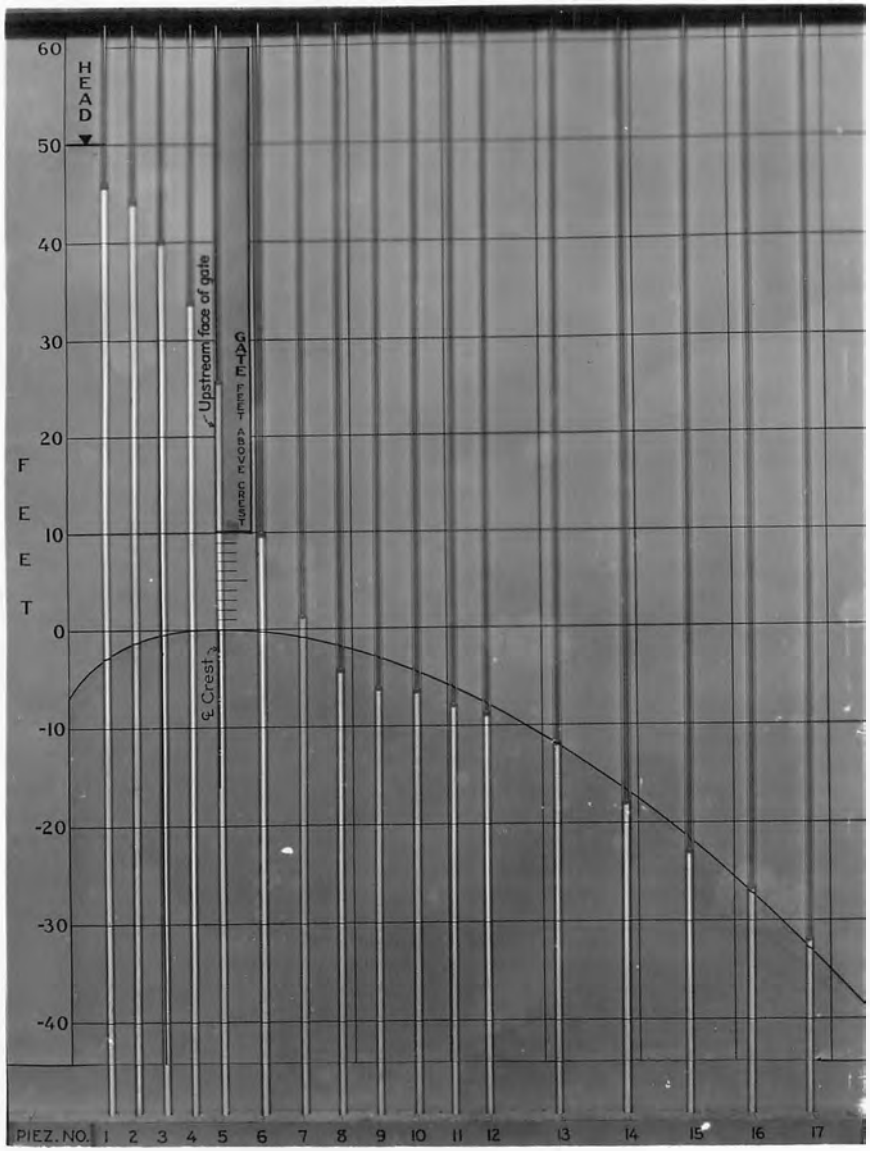
A - Gate opening of six feet



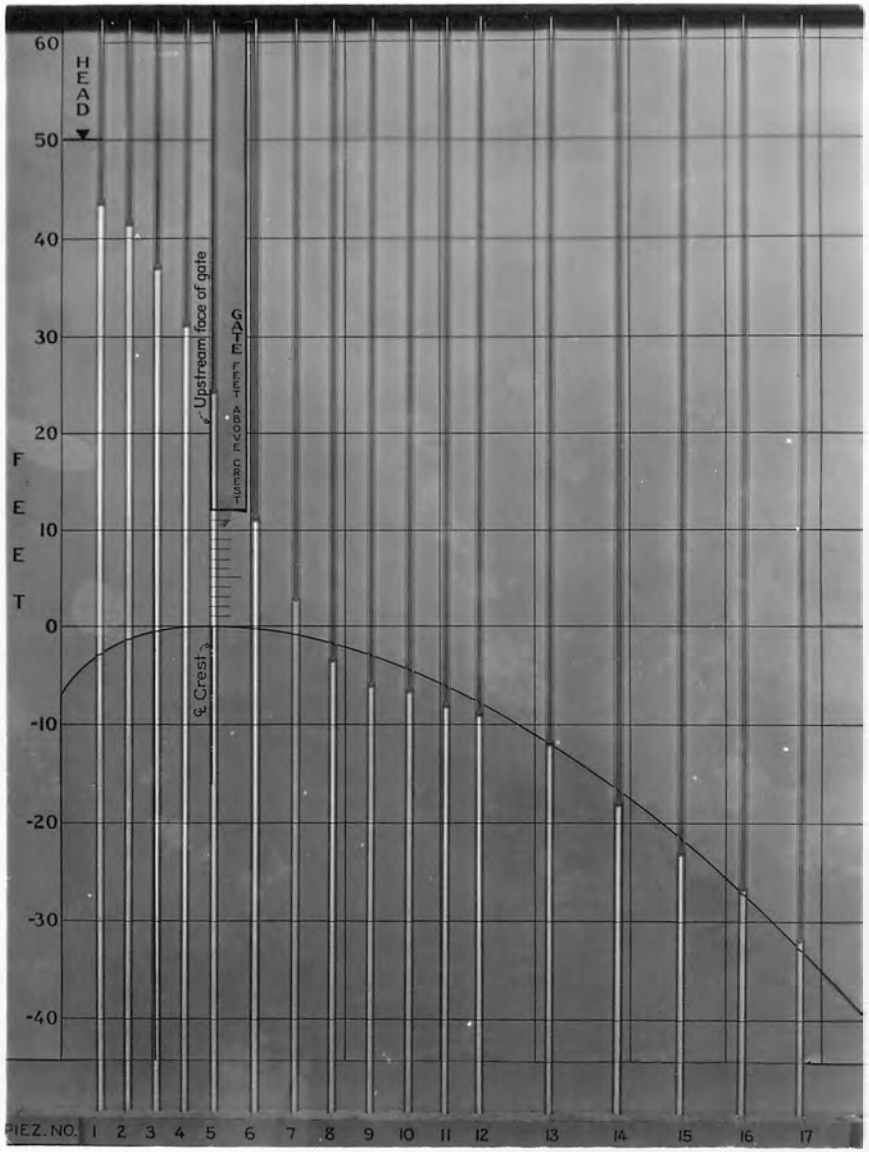
B - Gate opening of eight feet

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - FOR FIFTY FEET OF HEAD ON CREST

FIGURE 9



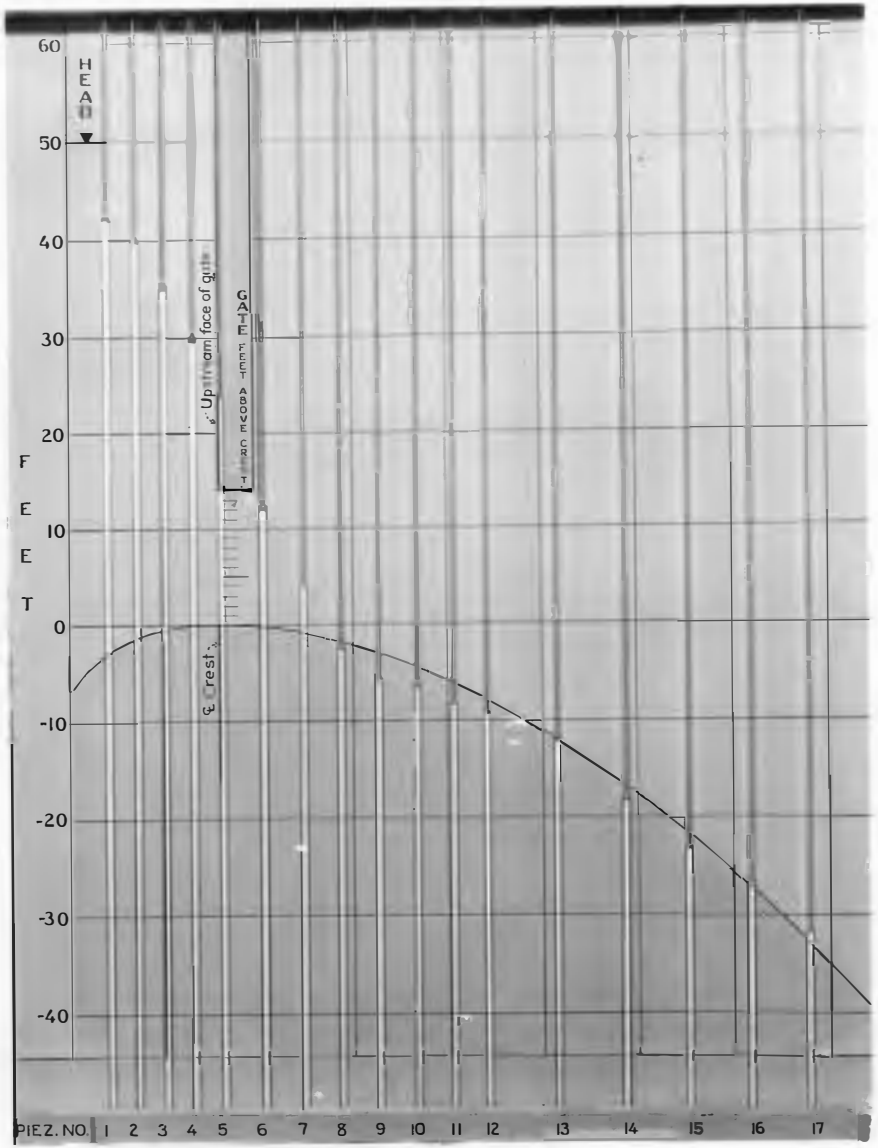
A - Gate opening of ten feet



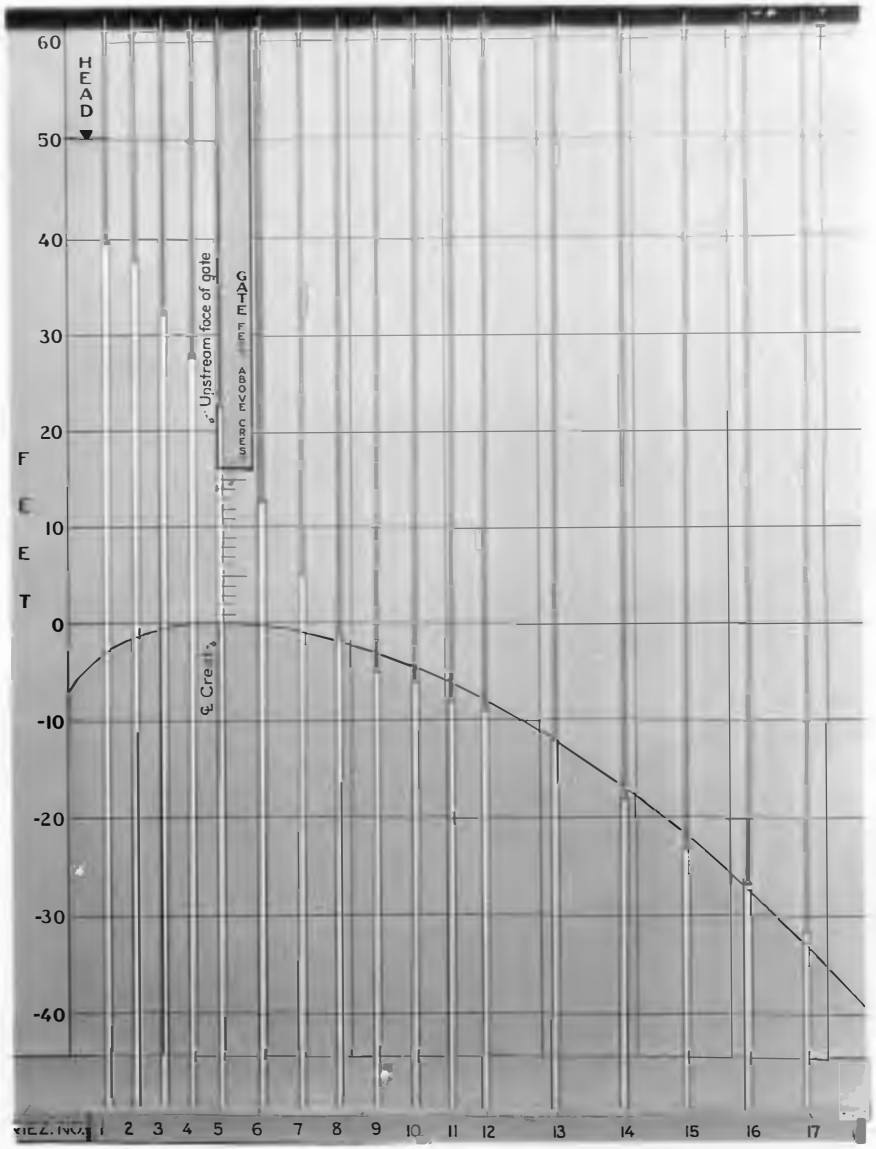
B - Gate opening of twelve feet

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - FOR FIFTY FEET OF HEAD ON CREST

FIGURE 10



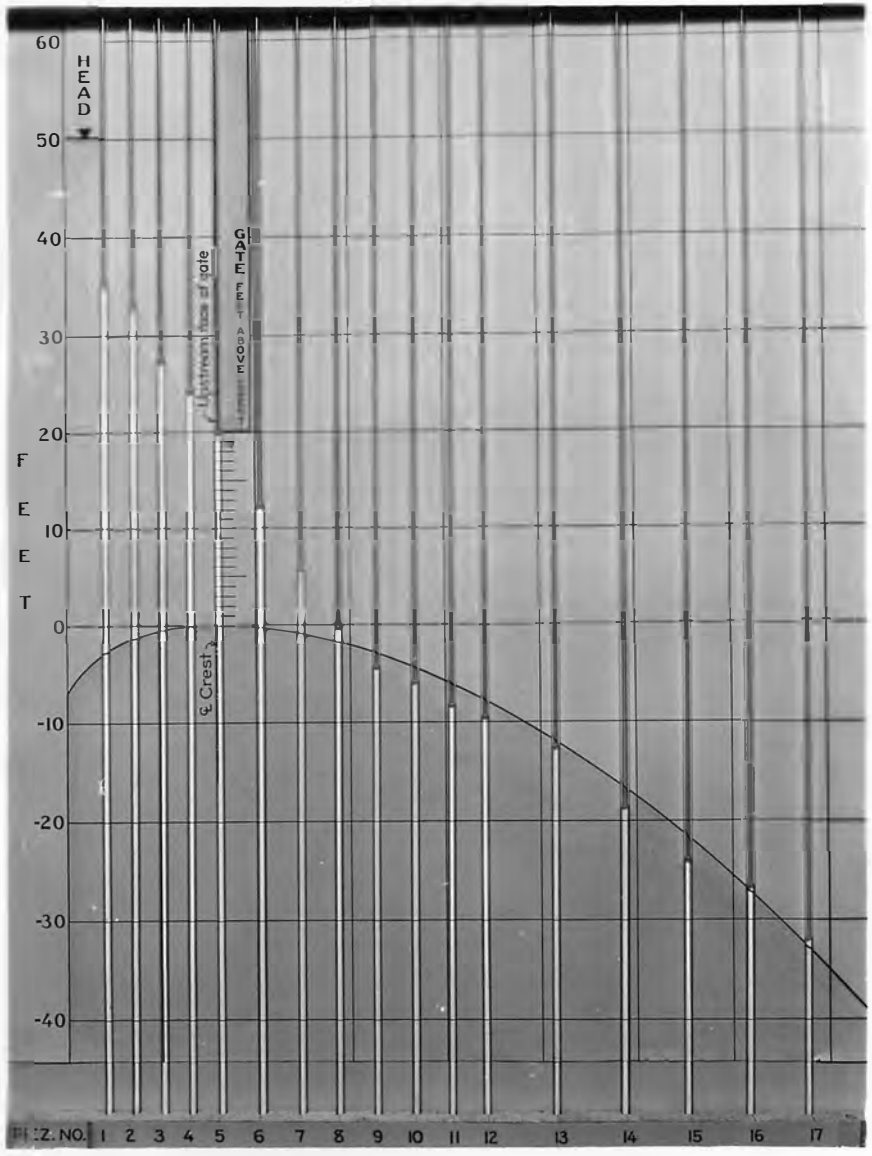
A - Gate opening of fourteen feet



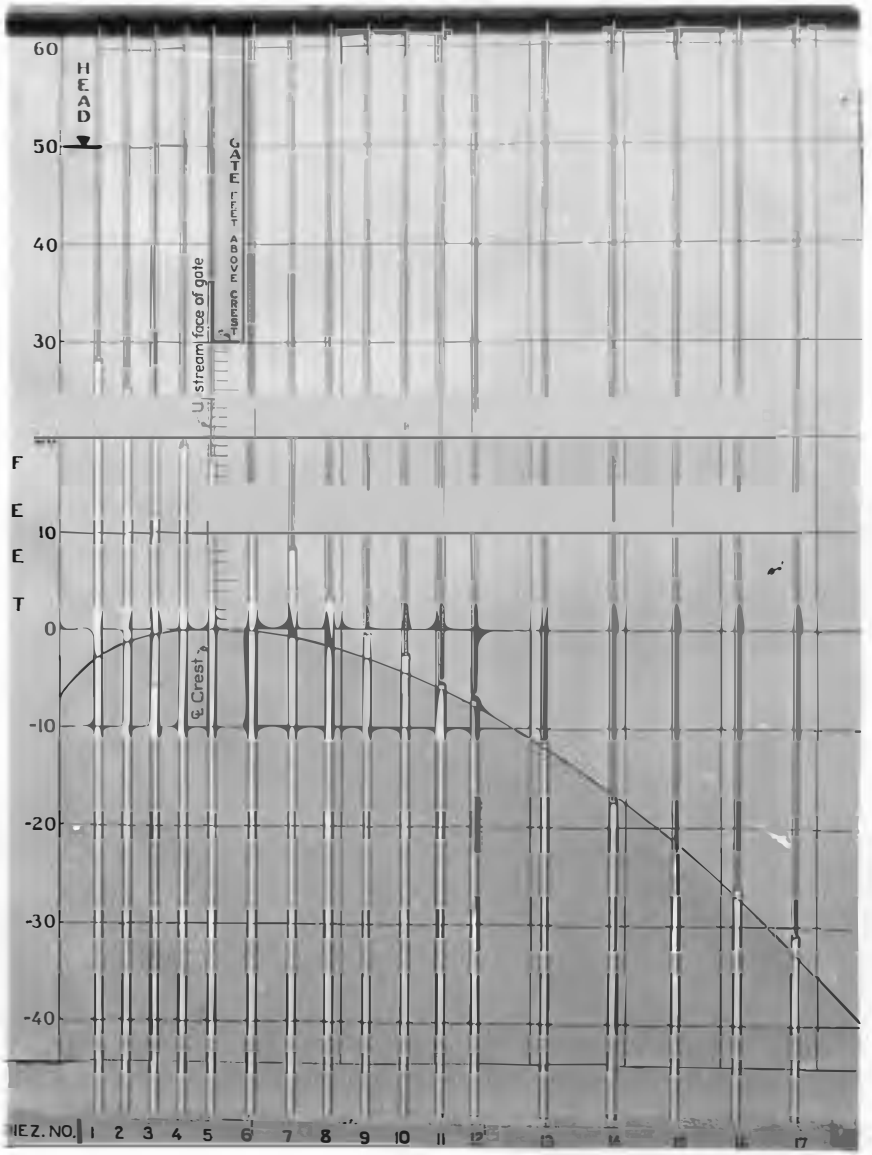
B - Gate opening of sixteen feet

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - FOR FIFTY FEET OF HEAD ON CREST

FIGURE 11



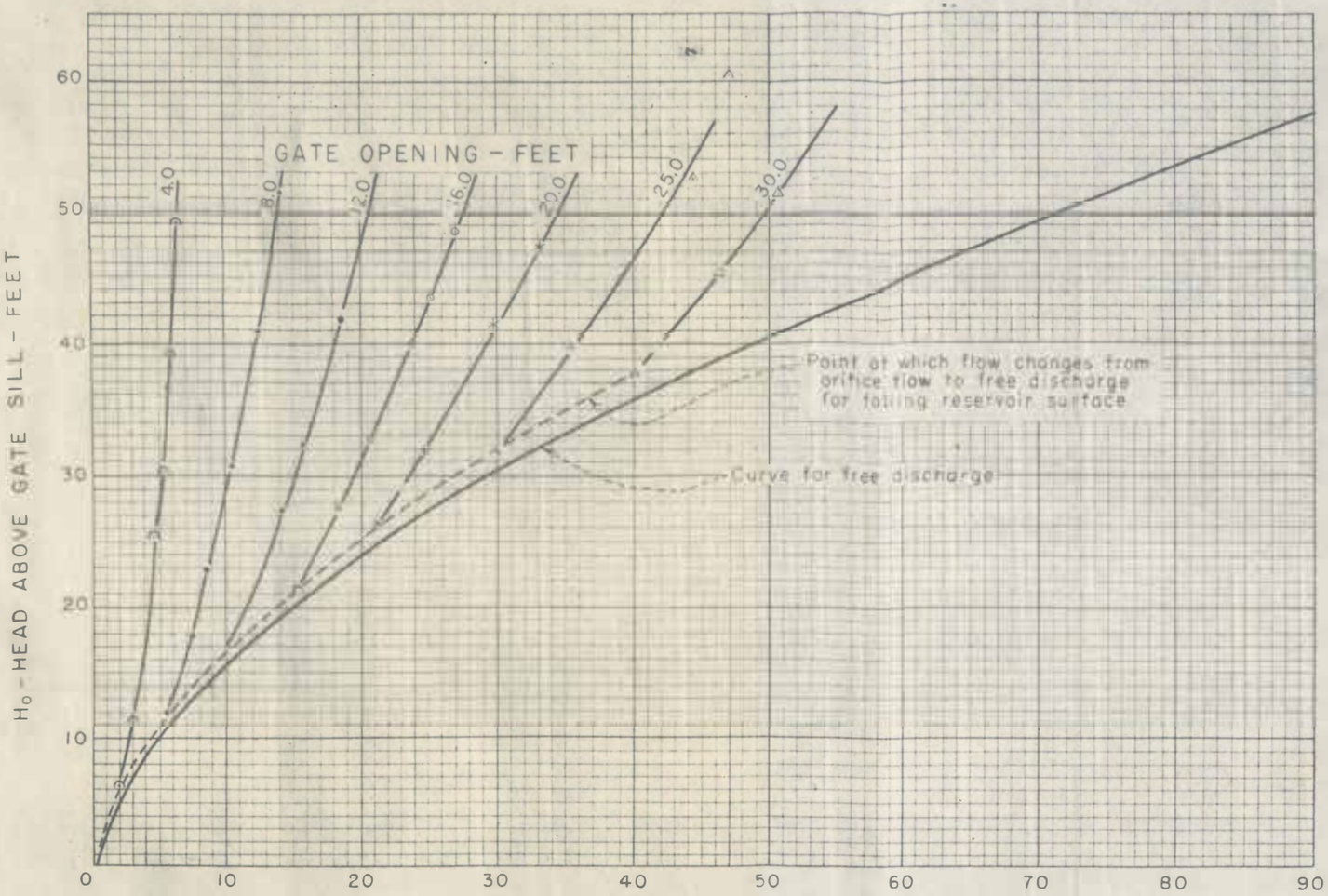
A - Gate opening of twenty feet

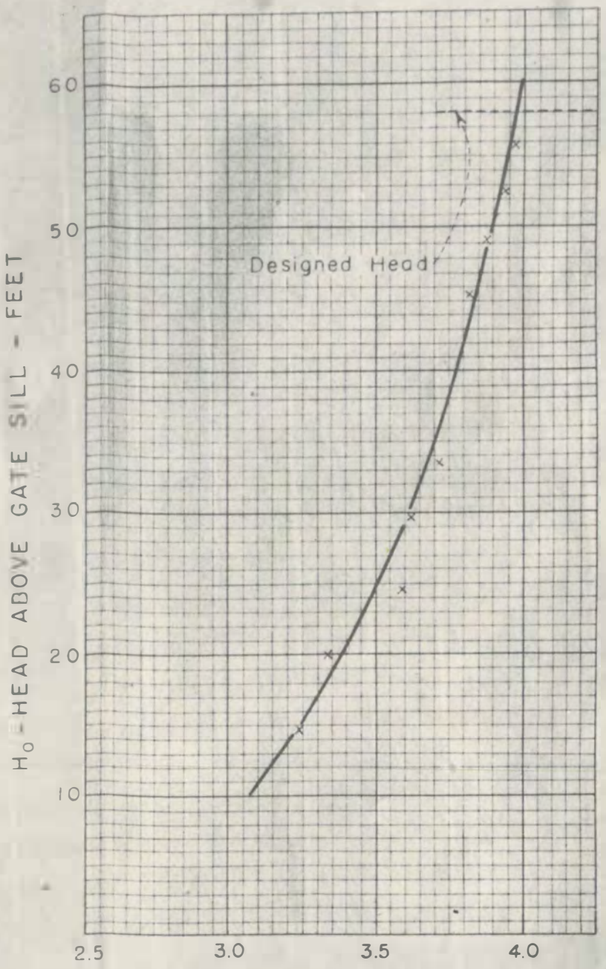


B - Gate opening of thirty feet.

DAVIS DAM SPILLWAY - PRESSURES ON OVERFALL FACE - FOR FIFTY FEET OF HEAD ON CREST

FIGURE 12





DAVIS DAM

CALIBRATION CURVES FOR ONE 50 BY 50 – FOOT SPILLWAY GATE

OBTAINED FROM A 1:50 SCALE MODEL

3.97 which is slightly larger than the design value of 3.93 obtained from Laboratory Report No. 122 for the original design.

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