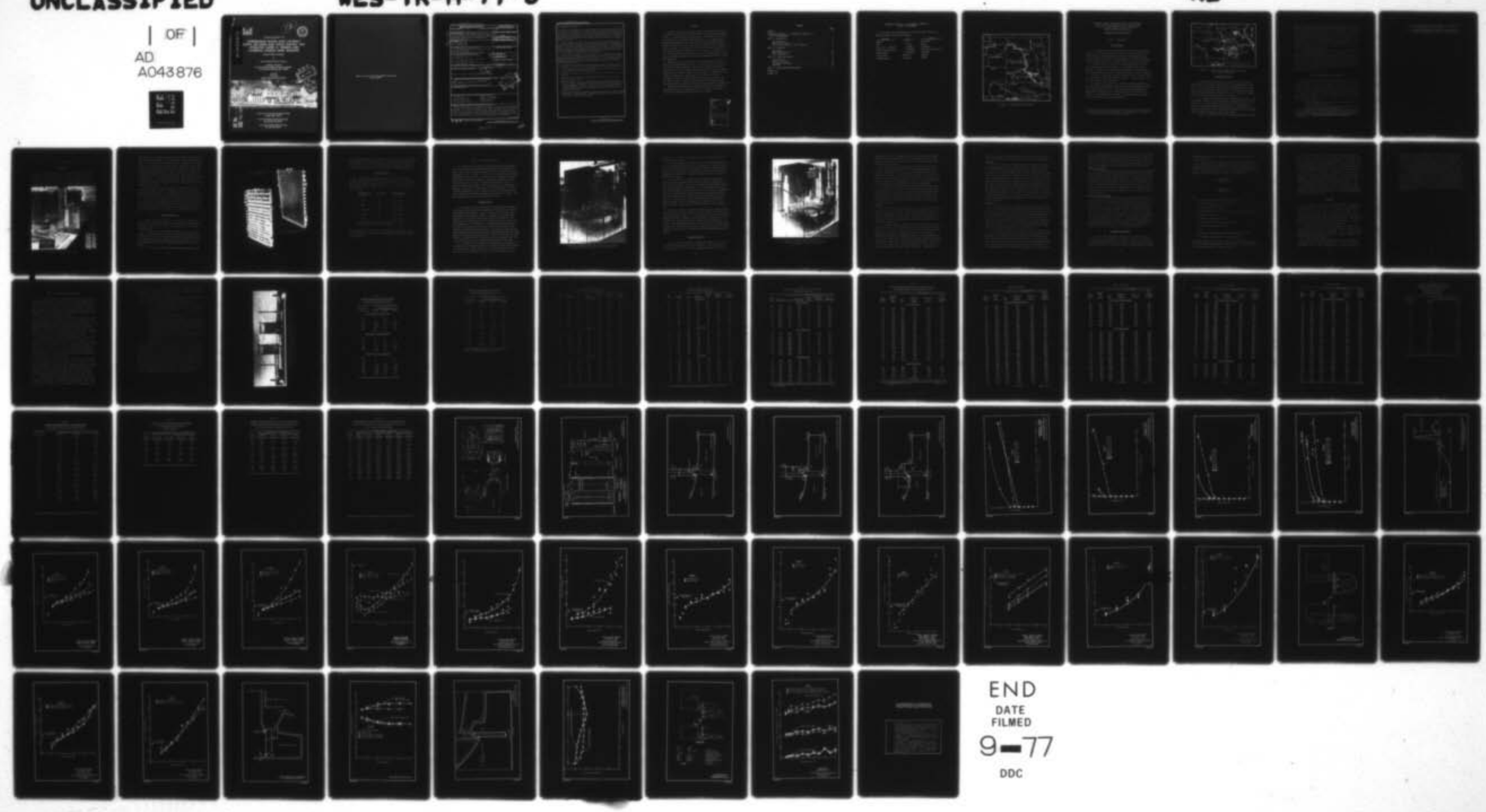
AD-A043 876 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
POWERHOUSE INTAKE GATE CATAPULT STUDY, BIG BEND DAM, SOUTH DAKO--ETC(U)
APR 77 J F GEORGE, G A PICKERING

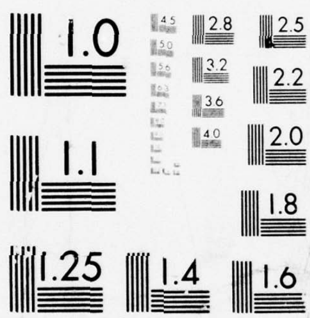
UNCLASSIFIED WES-TR-H-77-8 NL

| OF |

AD
A043876



END
DATE
FILMED
9-77
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL REPORT H-77-8

POWERHOUSE INTAKE GATE CATAPULT STUDY, BIG BEND DAM, SOUTH DAKOTA, AND STOCKTON, HARRY S. TRUMAN, AND CLARENCE CANNON DAMS, MISSOURI

Hydraulic Model Investigation

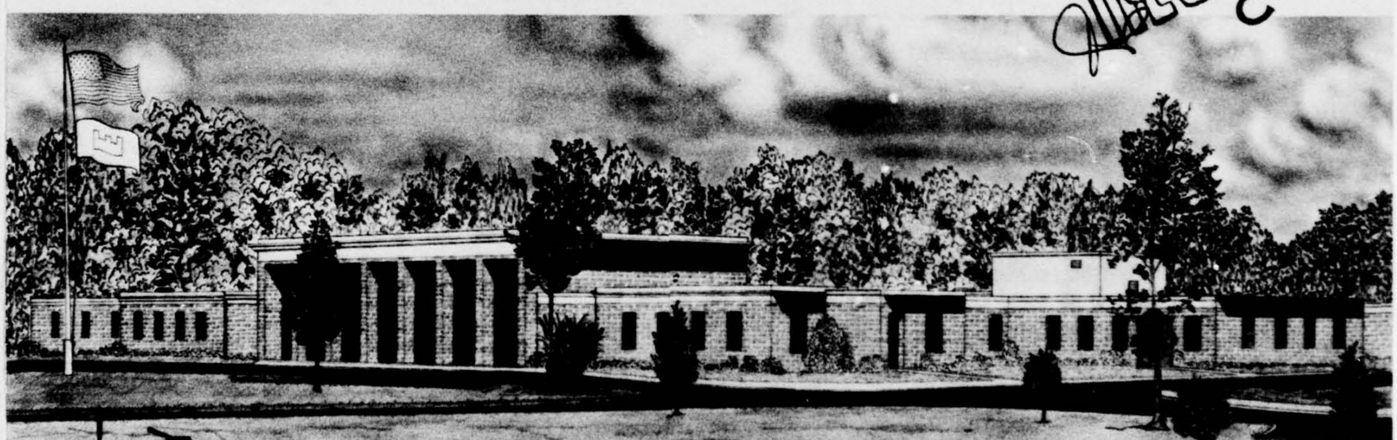
by

John F. George, Glenn A. Pickering

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

April 1977
Final Report

Approved For Public Release; Distribution Unlimited



Prepared for U. S. Army Engineer District, Omaha
Omaha, Nebr. 68102

U. S. Army Engineer District, Kansas City
Kansas City, Mo. 64106

U. S. Army Engineer District, St. Louis
St. Louis, Mo. 63101

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report H-77-8
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

(9)

4. TITLE (and Subtitle): (6) POWERHOUSE INTAKE GATE CATAPULT STUDY, BIG BEND DAM, SOUTH DAKOTA, AND STOCKTON, HARRY S. TRUMAN, AND CLARENCE CANNON DAMS, MISSOURI. Hydraulic Model Investigation.
5. TYPE OF REPORT & PERIOD COVERED: Final Report, Dec 73 - Jan 76
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) John F. George, Glenn A. Pickering
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station, Hydraulics Laboratory, P. O. Box 631, Vicksburg, Miss. 39180
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Engineer District, Omaha, Omaha, Nebraska 68102; U. S. Army Engineer District, Kansas City, Kansas City, Missouri 64106; U. S. Army Engineer District, St. Louis, St. Louis, Missouri 63101
12. REPORT DATE: (11) April 1977
13. NUMBER OF PAGES: 72
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

(12) 76p.

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(14) WES-TR-H-77-8

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Big Bend Dam
Clarence Cannon Dam
Electric power plants
Gates (Hydraulic structures)
Harry S. Truman Dam
Hydraulic structures
Intake structures
Stockton Dam

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Tests were conducted to determine the range of gate openings and hydraulic conditions at which the service gates at Big Bend, Stockton, and Clarence Cannon powerhouses can be used for watering-up the scroll case area. The test data should also be applicable to Harry S. Truman powerhouse. Measurements of gate catapult heights, uplift forces, discharge coefficients, and pressures throughout the system were made for various gate openings and pool elevations.

(Continued)

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

038100

20. ABSTRACT (Continued).

Although the model gate was suspended from a wire cable, cable stretch and tension were not simulated. Also, roller bearing and seal friction were somewhat greater in the model than in the prototype. Therefore, some caution should be exercised in application of the data to prototype simulations. For example, if any movement of the gate, however small, occurred in the model it should be assumed that the prototype gate will catapult; operation with these conditions should be avoided.

The discharge coefficients that were measured for flow underneath the gate were about as expected. However, the discharge coefficients for the back-of-gate orifices were considerably higher than had been expected. The back-of-gate orifice is actually a submerged, vertical short tube. There is not a plentiful supply of data concerning discharge coefficients for a vertical orifice, but the limited amount of information that is available indicates that the coefficients determined in this study are not unreasonable.

The pressures measured at various locations in the penstock, on the gate, and in the scroll case area were not indicative of a blow due to water hammer, although there was a pronounced change in pressures at the time when the scroll case became full and flow started up the gate slot. The pressures measured underneath the gate on the bottom structural member could not be directly related to the uplift force.

Although the data could not be generalized for specific design criteria, the following conclusions can be used as guidance for design of intake gates:

(a) If the combined back-of-gate orifice area is greater than the area of the gate opening, the gate will not catapult.

b/ Placing a skin plate on the back of the gate has little effect on uplift forces.

(c) The length of the approach penstock, within the limits tested, has no effect on uplift forces.

(d) The configuration of the area downstream from the gate has an effect on the uplift force. When the gate piers and wicket gate restrict flow there is less tendency for catapult. Thus, the intake gate with the greatest restrictions should be used for watering-up. It is possible that a long downstream penstock would cause greater uplift forces, but this was not proved in this study.

(e) A back-of-gate orifice configuration like that designed for Clarence Cannon powerhouse is very beneficial in reduction of uplift forces with the small gate opening required for watering-up.

PREFACE

The model investigation reported herein was authorized by the U. S. Army Engineer Division, Missouri River, on 23 July 1973 at the request of the U. S. Army Engineer District, Omaha. The studies were conducted by personnel of the Hydraulics Laboratory (HL), U. S. Army Engineer Waterways Experiment Station (WES) during the period December 1973 to January 1976 under the general supervision of Messrs. H. B. Simmons, Chief of HL, and J. L. Grace, Jr., Chief of the Structures Division, HL. The tests were conducted by Messrs. N. R. Oswalt, J. F. George, and H. H. Allen, under the supervision of Mr. G. A. Pickering, Chief of the Locks and Conduits Branch. This report was prepared by Messrs. George and Pickering.

During the course of the model investigation, Messrs. Alfred S. Harrison, Alexander Weremy, Robert O. Olson, and Robert E. Pletka of the Missouri Division; Messrs. Lloyd E. Sell, Frank Vovk, Ronald W. Bockerman, and Carl L. Brezden of the Omaha District; Messrs. Kenneth F. Crabtree, Jon M. Conley, Walter M. Linder, Dwayne A. Landenberger, and *Bernard Bubdenbender* of the Kansas City District; Mr. Albert L. McCormmach of the Walla Walla District; and Ms. Nancy H. Hsieh and Mr. Charles Denzel of the St. Louis District visited WES to discuss test results and to correlate these results with concurrent design work.

Directors of WES during the testing program and the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
cubic feet per second	0.02831685	cubic metres per second
pounds (mass)	0.4535924	kilograms
kips (force)	4448.222	newtons
kilowatt-hours	3,600,000	joules

Figure 1. Vicinity map, Big Bend Dam

POWERHOUSE INTAKE GATE CATAPULT STUDY, BIG BEND DAM, SOUTH DAKOTA, AND STOCKTON, HARRY S. TRUMAN, AND CLARENCE CANNON DAMS, MISSOURI

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototypes

1. Big Bend Dam is on the Missouri River in central South Dakota (Figure 1). All discharges from the dam are through the power units and the spillway. Eight generating units with a dependable capacity of 538,000 kw* are installed in the powerhouse. For full-gate operating conditions, these units will discharge 103,000 cfs from the reservoir.

2. Stockton Dam is at mile 49.5 on the Sac River about 2 miles east of Stockton, Missouri (Figure 2). One generating unit with a capacity of 45,200 kw is installed in the powerhouse. For full-gate operating conditions, this unit discharges 13,400 cfs from the reservoir.

3. Harry S. Truman Dam (formerly Kaysinger Bluff) is at mile 175 on the Osage River near Warsaw, Missouri (Figure 2). Six generating units will be installed in the powerhouse.

4. Clarence Cannon Dam will be located in northeast Missouri on the Salt River at approximately mile 63.0 above its confluence with the Mississippi River (Figure 2). Power generation plans provide for a pumped storage operation with a reregulation dam to be constructed about 9.5 miles downstream of the dam. The power plant will contain two turbines capable of generating 62,000 kw.

---

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

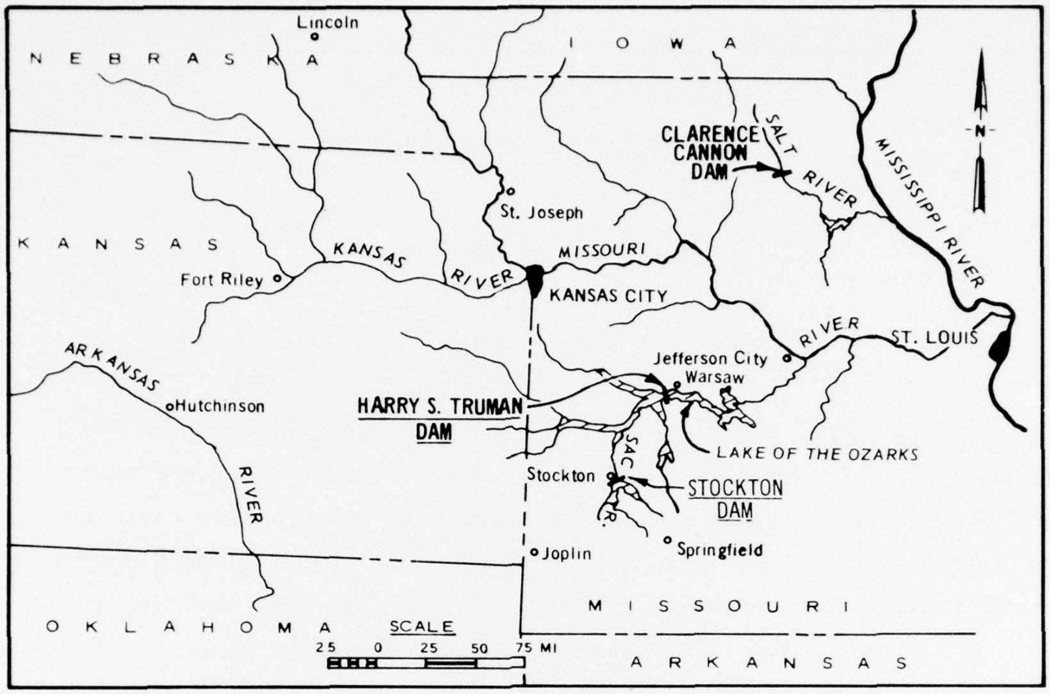


Figure 2. Vicinity map, Stockton, Harry S. Truman, and Clarence Cannon Dams

Operating Procedure

5. Procedures for watering-up the scroll case area between the intake gates and the wicket gates vary with each hydroelectric power plant design. Watering-up operations can be accomplished with bypass piping, but this procedure takes many hours. Additional piping could reduce the watering-up time; however, the cost of this type of modification to existing structures would be very high.

6. The intake gate is often used for watering-up operations. The watering-up operation can be accomplished by simply opening the intake gate 6 to 12 in. The operation requires very little time and thus avoids the additional expense and installation of bypass piping. This procedure has been used at Big Bend and is proposed for use at Stockton, Harry S. Truman, and Clarence Cannon power plants.

7. When the intake gate is used for watering-up purposes, however,

forces large enough to catapult the intake gate can develop. As the area between the intake gate and wicket gates becomes full during the watering-up operation, the water passes through an opening between the downstream side of the intake gate and the gate slot. This area acts as an orifice and is referred to as the back-of-gate orifice. If this orifice width or combination of orifice widths (dependent on number of bays) is smaller than the gate openings, the back-of-gate orifice could restrict the flow of water into the gate slot enough to cause hydraulic forces to develop that could catapult the intake gate.

8. When this procedure was used for watering-up at Mossyrock Dam* of the city of Tacoma, Washington (not a Corps-operated project), an intake gate weighing 145 kips was catapulted approximately 40 ft up the gate slot. Also, at Dworshak Dam while a maintenance crew was attempting to barely open an emergency gate upstream of a closed service gate, the emergency gate weighing only 27.7 kips catapulted 249 ft to the top of the gate slot. Fortunately, the gate was skewed in the top of the slot and did not fall back down the slot.

Need for and Purpose of Model Analysis

9. During the design and operation of intake gates for watering-up purposes, many assumptions must be made because of inadequate design guidance. Sufficient data are not available to determine a safe relationship between the powerhouse configuration, gate-lip orifice, back-of-gate orifice, and reservoir head. For these reasons, a model study was considered necessary to determine the behavior of penstock intake gates during watering-up operations. Specifically, the model study was to determine the following:

- a. The discharge coefficients for the gate-lip orifice and the back-of-gate orifice.
- b. The effect of various size back-of-gate orifices on uplift forces during watering-up operations.

---

* R. A. Robertson and J. W. Ball, "Model Study of Power Intake Gate of Mossyrock Dam," Journal of the Hydraulics Division, ASCE, Vol. 97, July 1971.

c. The effect of adding a skin plate on the downstream face of the intake gate on uplift forces.

d. The overall hydrodynamic phenomena causing the gate to catapult and methods of measuring tne related forces.

PART II: THE MODEL

Description

10. The model (Figure 3) was constructed to a scale of 1:16 and reproduced a service gate, three service gate slots, the penstock, and the scroll case configuration for the Big Bend powerhouse (Plate 1). The penstock, gate slots, and scroll case were constructed of transparent plastic to permit observations of flow conditions. The penstock

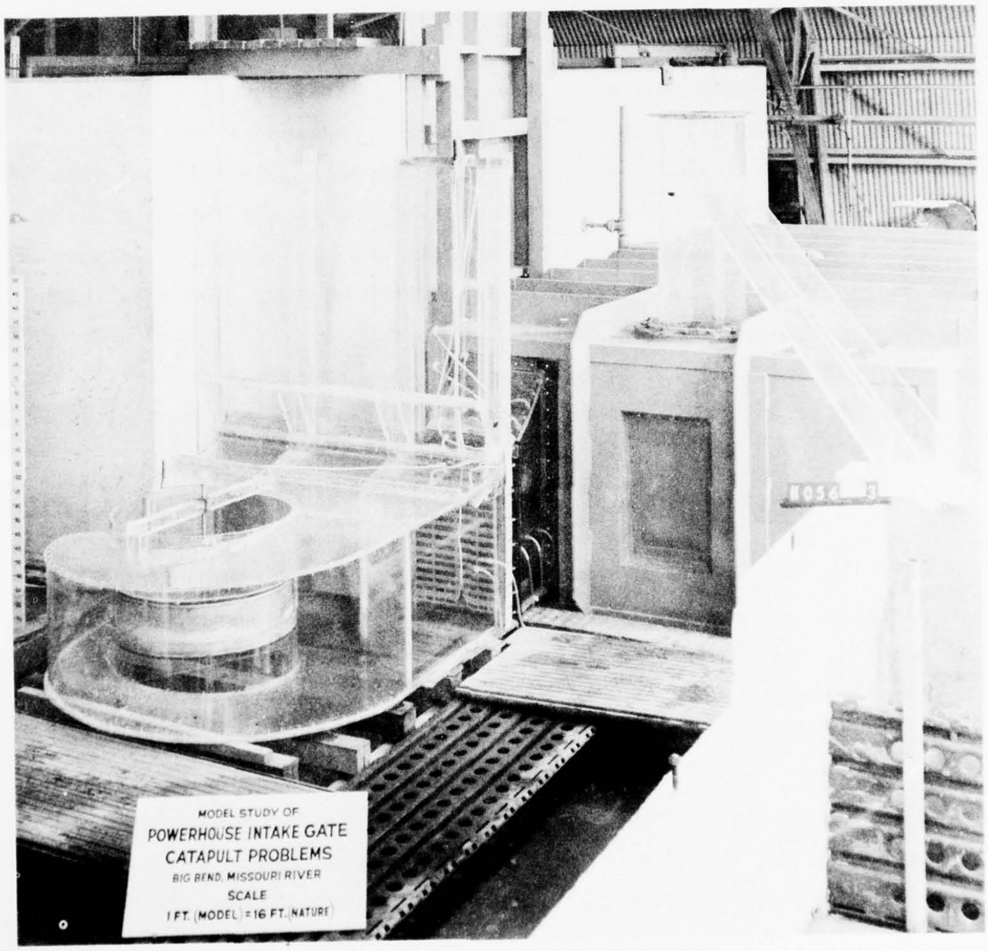


Figure 3. General view of model

was connected to a pressure tank with an overflow pipe that extended to the reservoir head desired. A circular wicket gate was constructed of sheet metal and provided a quick-action closure capability. All members of the service gate, shown in Plate 2, were reproduced in detail with respect to size, shape, and weight and were constructed of sheet metal. Roller bearings were mounted on the gate to allow it to traverse the gate slots with minimum friction. Rubber seals were attached to the upstream side of the gate and on the gate lip. The model gate is shown in Figures 4 and 5. The weight of the service gate was adjusted for various test conditions by adding or removing lead weights on the downstream side of the gate.

11. The service gate was suspended by a cable during tests to determine the catapult height. The cable was replaced with a rigid connection, which included a 0.5-in.-diam rod with a 150-lb load cell, during tests to measure the uplift forces acting on the intake gate.

12. The model was constructed so that modifications for various size back-of-gate orifices could be reproduced easily. The model also had the capability for reproducing flow through any one of the three gate bays by shifting the scroll case and the downstream portion of the model to different positions relative to the penstock and test gate.

Model Appurtenances

13. Water used in the operation of the model was supplied by a recirculating system, and discharges were measured by a venturi meter. Different designs along with various flow conditions were recorded photographically.

14. Piezometers were installed throughout the model to measure pressures. Also, pressures were measured with pressure cells mounted at various locations in the scroll case, penstock, overflow pipe, and in the bottom and the upstream side of the service intake gate. The fast-response transducers used in measuring pressures were rated at 1000 Hz.

15. All force and pressure-time histories were synchronized and

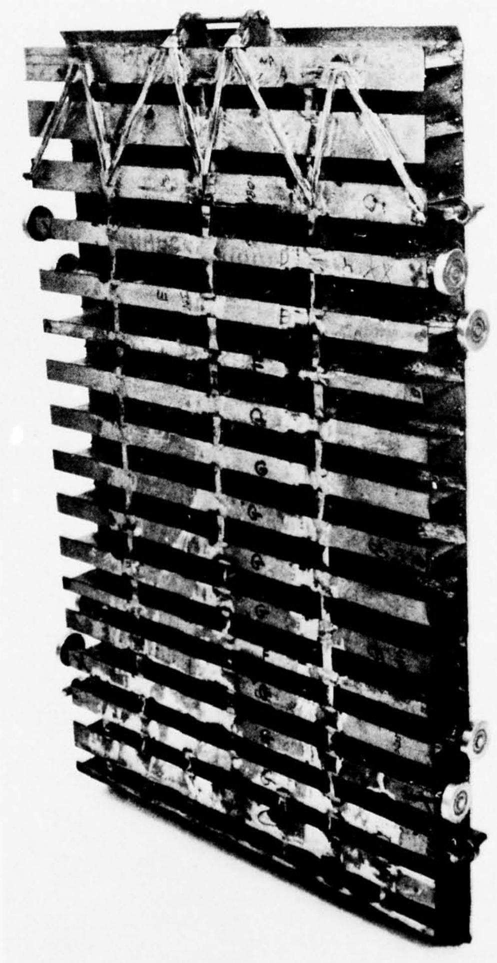


Figure 4. Upstream side of intake gate

Figure 5. Downstream side of intake gate

were recorded graphically on a commercial recorder. The sensing elements (mechanical-to-electrical conversion devices) located at various points on the model were connected by shielded cables to amplifiers where the outputs were stepped up to the level required for graphical recording.

Scale Relations

16. The accepted equations of hydraulic similitude, based on Froudian relations, were used to express mathematical relations between the dimensions and the hydraulic quantities of the model and prototype. General relations for transfer of model data to prototype equivalents are as follows:

Characteristic	Dimension*	Model:Prototype
Length	L	$L_R = 1:16$
Area	L_R^2	$A_R = 1:256$
Time	$L_R^{1/2}$	$T_R = 1:4$
Discharge	$L_R^{5/2}$	$Q_R = 1:1024$
Weight	L_R^3	$W_R = 1:4096$
Force	L_R^3	$F_R = 1:4096$

* Dimensions are in terms of length.

Model measurements of discharge, time, weight, and force can be transferred quantitatively to prototype equivalents by means of the preceding scale relations.

PART III: TESTS AND RESULTS

17. The behavior of penstock intake gates with various back-of-gate orifice widths during watering-up operations was studied in the model. All of the tests were conducted with the Big Bend scroll case configuration shown in Plate 1. Tests were conducted with the following back-of-gate orifice widths: 6.625 in., Plate 3 (Stockton Dam) which would also be applicable to Harry S. Truman Dam; 8.6875 in., Plate 1 (Big Bend Dam); 12 in., Plate 4 arbitrarily chosen; and 71.63 in., Plate 5 (Clarence Cannon Dam). Data were obtained for a wide range of hydraulic conditions for possible use at other power plants. Tests included determination of gate catapult heights, uplift forces on the gate, discharge coefficients, and pressures throughout the model. Results pertinent to these tests are discussed below.

Catapult Tests

18. Catapult tests were conducted to determine the safe range of gate openings during watering-up operations for Big Bend and Stockton back-of-gate configurations. Each test began with the desired head, predetermined gate opening, tailwater elevation, and a steady flow beneath the test gate and through the wicket gate (Figure 6). The wicket gate was quickly closed (1 sec, model) to fill the scroll case area downstream of the intake gate. The intake gate was subjected to an uplift force after the scroll case filled and flow began to pass through the three back-of-gate orifices. All catapult tests were conducted with the test gate in the left bay (looking downstream) and dummy gates in the middle and right gate bays. These tests did not take into account the unknown effects of cable stretch or the variable seal friction, since they could not be accurately reproduced in the model.

19. The gate roller friction was measured outside the model on a horizontal piece of plastic similar to the model bearing plate material. The friction force varied from 14 to 15.5 kips (prototype) when the gate was loaded to simulate the force caused by the head due to the

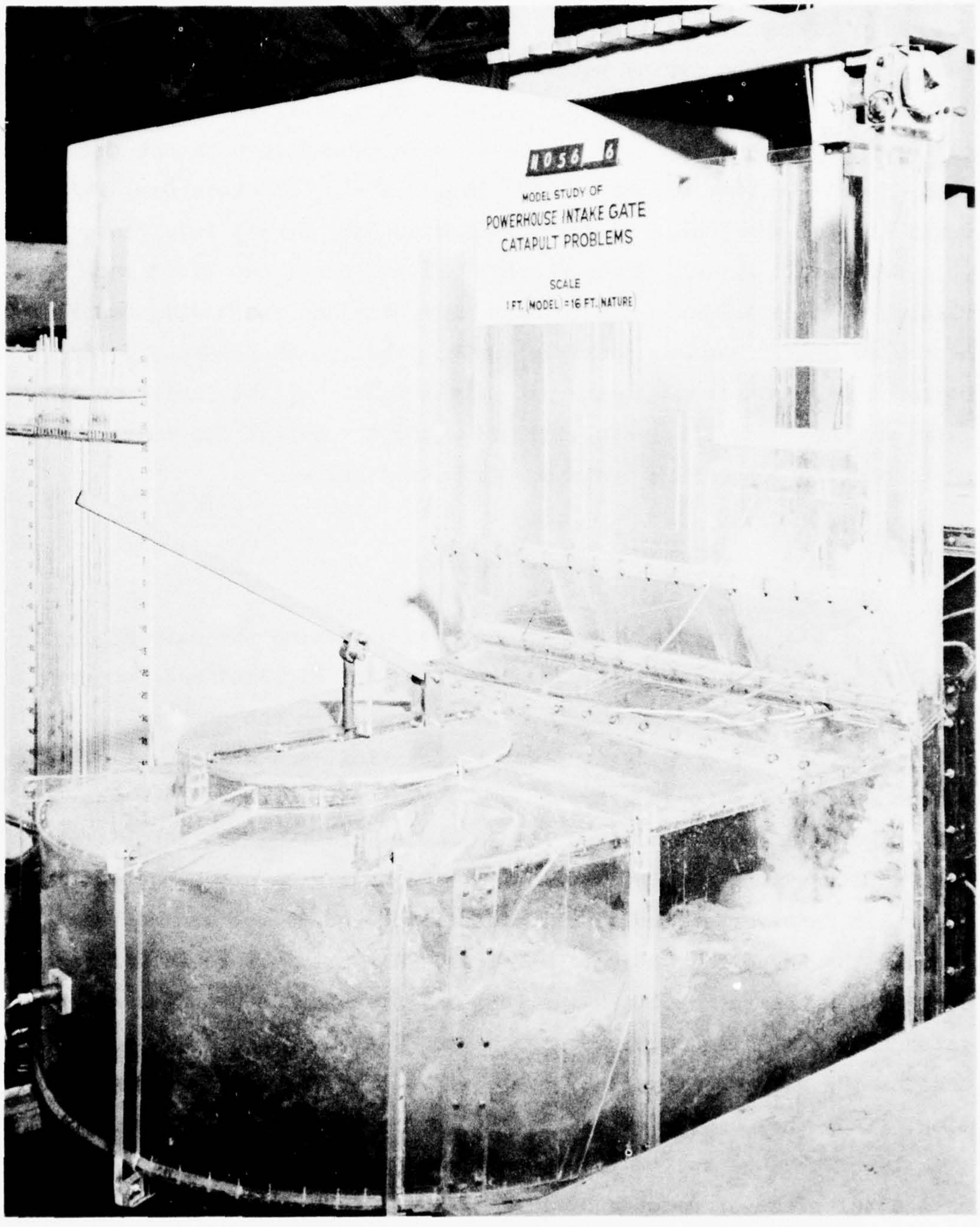


Figure 6. General view of flow conditions in Big Bend Dam powerhouse, gate opening = 3.0 ft, 100-ft head

Big Bend pool. This was considerably more than the computed friction in the prototype (5 kips).

20. During catapult tests uplift forces could not be measured with the cable connection, but the heights of catapult were measured for each test. Identical tests would not reproduce identical catapult heights, although close comparisons were observed in most tests. The height of catapult was considered less significant than the initial conditions required for catapult.

21. The weight of the intake gate was varied and subjected to different heads to determine what effect the change in weight had on the height of catapult. Tests were conducted with the Big Bend back-of-gate orifice using gates weighing 110, 137, and 150 kips (prototype) that were subjected to initial heads of 96, 120, and 140 ft. Additional tests were conducted with Stockton conditions using a gate weighing 131 kips (prototype) that was subjected to initial heads of 100, 120, and 140 ft. The results of these tests indicate that no catapult problems should occur if the intake gate is opened 1 ft or less for these conditions. These data are shown in Plates 6-9 and in Tables 1 and 2.

22. Other catapult tests were conducted using the Clarence Cannon back-of-gate orifice design with the Big Bend scroll case configuration and bay arrangement (Figure 7). The results of these tests using a gate weighing 131 kips (prototype) that was subjected to heads up to 120 ft indicated the intake gate will not catapult for gate openings of 5 ft or less. The considerable difference in results of the Clarence Cannon catapult tests when compared with the previous Big Bend and Stockton Dam catapult tests was due to the radically different back-of-gate orifice design.

Total Uplift Forces

23. Tests were conducted to determine the uplift forces acting on the intake gate during watering-up operations. The uplift force recorded includes the effect of gate submergence and the uplift force

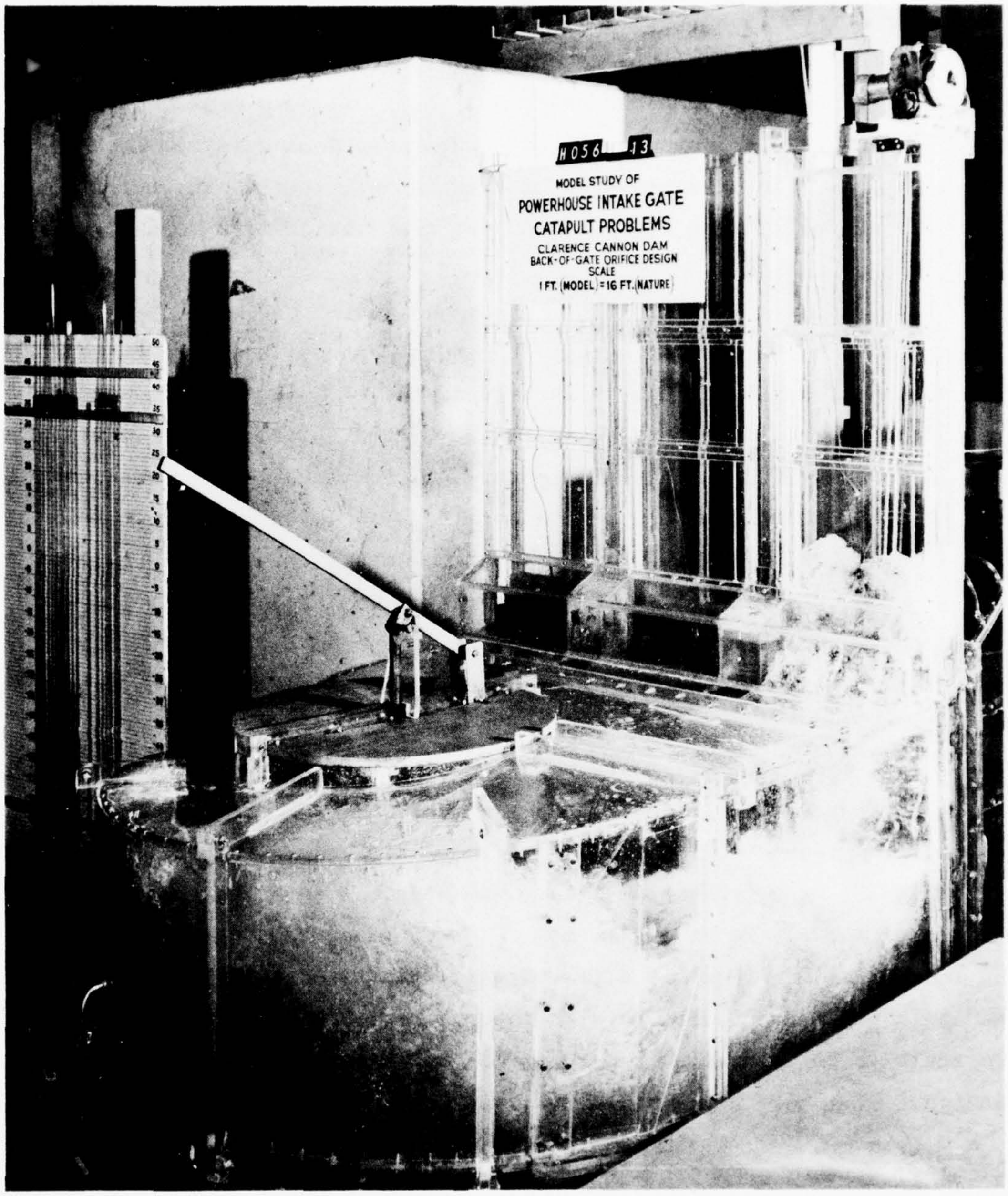


Figure 7. General view of flow conditions with Clarence Cannon back-of-gate orifice design. Gate opening = 3.0 ft, 100-ft head

required to overcome the downward force on the gate caused by leakage over the top and around the sides of the gate (Figure 6). This force is referred to as the total uplift force and was measured from the strip chart as shown in Plate 10.

24. The total uplift force data that are plotted from the rigid connection tests were obtained at the time the maximum uplift force occurred. The duration of these forces was dependent on the initial head and gate opening. The actual head on the gate at the time of maximum uplift varied somewhat from the initial head set before each test and was recorded for use in analysis of data. For all rigid connection tests the weight of the intake gate was 131 kips (prototype).

25. Uplift forces were measured using back-of-gate orifice widths of 6.625, 8.6875, 12, and 71.63 in. The majority of the uplift forces were obtained with the test gate in the left bay (looking downstream) and dummy gates in the middle and right gate bays. The same testing procedure used in the catapult tests was followed for the rigid connection tests with various gate openings subjected to 80-, 100-, and 120-ft initial heads.

Left bay

26. Test results with the test gate in the left bay for the 6.625-, 8.6875-, and 12-in. back-of-gate orifice widths indicate that uplift forces increase with gate opening and head; however, they decrease with increased back-of-gate orifice widths. These data are compared in Plates 11-13. Uplift forces and pressures measured during these tests are shown in Tables 3-5.

27. Different results, however, were indicated with the Clarence Cannon back-of-gate orifice design (71.63-in. width) for the same test conditions. The results indicate that the uplift forces with small gate openings decrease with an increase in head (Plate 14 and Table 6). Apparently the physical configuration allowed a greater downward force to act on the intake gate. Uplift forces were also obtained for various gate openings subjected to a 50-ft initial prototype head. The results show that the uplift forces were approximately the same throughout the range of gate openings tested (Plate 14, Table 6). Generally, all

uplift forces with the Clarence Cannon design for gate openings below 5.0 ft were relatively low compared to the dry weight of intake gates.

Right bay

28. Uplift forces were measured with the test gate in the right bay (looking downstream) with Stockton conditions reproduced to determine what effect this would have on these forces. Dummy gates were positioned in the left and middle bays. The uplift forces were obtained using various gate openings subjected to 100- and 120-ft initial heads and are presented in Table 7. Comparisons of uplift forces for Stockton conditions measured with flow entering the scroll case through the right bay relative to the left bay (looking downstream) indicate that the uplift forces are less when the right intake gate is used for watering-up. This reduction in uplift forces was attributed to the scroll case configuration, pier alignment, and location of the wicket gates in relation to the right bay (Plate 1). These data, presented in Plates 15 and 16, also indicate that no catapult problems should occur if the gate is opened 1 ft or less.

Middle bay

29. Additional tests were conducted to determine the uplift forces acting on the middle intake gate during watering-up operations with Big Bend conditions reproduced. The uplift forces were obtained with various gate openings subjected to 80-, 100-, and 120-ft initial heads and are provided in Table 8. Comparisons of the total uplift forces for Big Bend conditions measured with flow entering the scroll case through the center bay relative to the left bay (looking downstream) are shown in Plates 17-19. These data indicate no significant difference in uplift forces with the flow entering either one of these bays.

30. Tests were conducted to determine the effect on uplift forces with one, two, and three back-of-gate orifices open with the same test conditions. The tests were conducted using Big Bend conditions with the test gate in the middle bay and dummy gates in the left and right bays. The uplift forces were measured for various gate openings subject to an 80-ft initial head. The uplift forces were obtained with all three back-of-gate orifices opened, the right gate slot sealed, the left

gate slot sealed, and both left and right gate slots sealed. The results show that the uplift forces are less when the right slot is sealed compared with the left slot being sealed. This is attributed to the position of the right bay in relation to the powerhouse geometry. Plots of these data are shown in Plate 20, and the data are listed in Table 9.

Effect of skin plate

31. The intake gate was tested with a skin plate on the downstream side throughout its entire length using Stockton's back-of-gate orifice width. Uplift forces were measured with the test gate in the left bay and dummy gates in the middle and right bays. The forces were obtained for various gate openings subject to initial heads of 100 and 120 ft. Results of these tests indicated that the skin plate had little effect on the uplift forces acting on the intake gate. These data and data obtained without a skin plate are compared in Plates 21 and 22, and are listed in Table 10.

Effect of penstock length

32. Other tests were conducted with Big Bend conditions to determine the effect of the penstock length upstream from the service gate on the total uplift forces. The penstock length was increased from 24 (previous tests) to 120 ft as shown in Plate 23. Uplift forces were obtained with various gate openings subjected to initial heads of 80, 100, and 120 ft. The test gate was placed in the left bay with dummy gates in the other two bays. Comparisons of data with the two lengths are shown in Plates 24-26 and Table 11. No significant difference in the magnitude and duration of the uplift forces resulted with the different lengths of penstock. This was probably due to the penstock extension having little effect on the upstream flow pattern.

Discharge Coefficients

33. Tests were conducted to determine the separate discharge coefficients for flows beneath the intake gate (gate-lip orifice) and through the back-of-gate orifice. These tests were conducted with flow under the test gate in the left bay (looking downstream) and up through

the back-of-gate orifice. A schematic drawing of the test conditions is shown in Plate 27.

34. For each test, the water surface in the right and middle gate slots was allowed to reach equilibrium so that all of the flow passing underneath the gate was forced through the back-of-gate orifice in the left bay and then transferred to a box with a V-notch weir for measuring purposes. The equations used to compute the coefficients are

$$C_1 = \frac{Q_1}{\sqrt{2g\ H_1} \times \ell \times d}$$

$$C = \frac{Q}{\sqrt{2g\ H_2} \times \ell \times D}$$

where

C_1 = back-of-gate orifice discharge coefficient

Q_1 = flow through back-of-gate orifice

g = acceleration due to gravity

H_1 = head differential between gate well 1 and gate wells 2 and 3

ℓ = width of gate bay

d = depth of back-of-gate orifice

C = gate-lip orifice discharge coefficient

Q = flow through gate-lip orifice

$Q = Q_1$

H_2 = head differential between pool and gate wells 2 and 3

D = height of gate-lip orifice or gate openings

Each gate opening was tested with a minimum of three heads varying from 75 to 150 ft above the intake gate invert. A plot of the coefficients for various gate openings is shown in Plate 28.

35. The coefficients for the back-of-gate orifice ranged from about 0.90 to 1.0 for the Stockton, Big Bend, and 12-in. orifices. This was considerably higher than had been anticipated (0.25 to 0.60). However, this coefficient is a submerged orifice coefficient and does not include other uplift factors such as drag. In the determination of the Clarence Cannon back-of-gate orifice coefficient, two orifice widths D_1 and D_2 were used (Plate 29). The dimension D_1 was used as the orifice width until D_2 became less than D_1, then D_2 was used. The dimension D_2 varied with each gate opening. This shift in control is indicated by the discontinuity in the curve shown in Plate 30. The results indicate the discharge coefficient varies from 0.60 to 0.80.

36. The discharge coefficients for the gate-lip orifice ranged between 0.62 and 0.65 for all conditions tested. Varying the head had little effect on the discharge coefficients for either the back-of-gate orifice or the gate-lip orifice.

Pressures

37. Pressures were obtained at various locations throughout the model during all rigid connection tests in an effort to determine what factors contributed to the intake gate catapulting. Pressures were measured in the scroll case area, underneath the intake gate, on the upstream side of the intake gate, in the penstock, and in the standpipe (to measure the head pool) during watering-up operations. The locations where these pressures were measured are shown in Plate 31. Pressures measured during various tests are shown in Tables 3-6.

38. Theoretically, the uplift forces measured in previous tests should be equal to the pressure acting under the gate multiplied by the projected area of the intake gate (thickness × width). This was not the case with pressures recorded from model tests, and the reason for the difference was not readily apparent.

39. Pressure fluctuations occurred in the scroll case during watering-up but were quickly dampened as the flow passed through the back-of-gate orifice. These fluctuations did not appear to have the

characteristics of a water hammer-type shock wave. Pressures also were measured in the penstock area and on the upstream side of the intake gate and were found to be approximately equal to the reservoir head (Plate 32). The turbulent flow around the bottom of the intake gate and in the scroll case prevented the determination of how much the flow under the gate lowers the pressure on the bottom side of the intake gate.

40. Pressure-time histories were analyzed in an attempt to generalize the existing data to establish design criteria for other powerhouse watering-up operations. However, these efforts were unsuccessful. Major factors causing the gate to catapult other than the shift in flow control from under the gate to the back of the gate were not isolated; therefore, the test results appear to be valid only for the conditions tested and applicable to installations with similar structural geometry and reservoir heads.

PART IV: DISCUSSION AND CONCLUSIONS

41. Tests were conducted to determine the range of gate openings and hydraulic conditions at which the service gates at Big Bend, Stockton, and Clarence Cannon powerhouses can be used for watering-up the scroll case area. The test data should also be applicable to Harry S. Truman powerhouse. Measurements of gate catapult heights, uplift forces, discharge coefficients, and pressures throughout the system were made for various gate openings and pool elevations.

42. Although the model gate was suspended from a wire cable, cable stretch and tension were not simulated. Also, roller bearing and seal friction were somewhat greater in the model than in the prototype. Thus, some caution chould be used in application of the data to prototype simulations. For example, if any movement of the gate, however small, occurred in the model, it should be assumed that the prototype gate will catapult; operation with these conditions should be avoided.

43. The discharge coefficients that were measured for flow underneath the gate were about as expected. However, the discharge coefficients for the back-of-gate orifices were considerably higher than had been expected. The back-of-gate orifice is actually a submerged, vertical short tube. There is not a plentiful supply of data concerning discharge coefficients for a vertical orifice, but the limited amount of information that is available indicates that the coefficients determined in this study are not unreasonable.

44. The pressures measured at various locations in the penstock, on the gate, and in the scroll case area were not indicative of a blow due to water hammer, although there was a pronounced change in pressures at the time when the scroll case became full and flow started up the gate slot. The pressures measured underneath the gate on the bottom structural member could not be directly related to the uplift force.

45. Attempts were made to generalize the data so that an uplift force could be computed when the head, gate opening, and orifice width are known. However, these attempts were not successful. Even if this could have been accomplished, it is doubtful that the information could

be used at installations where the scroll case configuration is different from the one tested, especially if the heads are out of the range tested. The basic data are furnished in tabular form.

46. Although the data could not be generalized for specific design criteria, several conclusions were drawn from the tests. These conclusions can be used as guidance for design of intake gates:

- a. If the combined back-of-gate orifice area is greater than the area of the gate opening, the gate will not catapult.
- b. Placing a skin plate on the back of the gate has little effect on uplift forces.
- c. The length of the approach penstock, within the limits tested, has no effect on uplift forces.
- d. The configuration of the area downstream from the gate has an effect on the uplift force. When the gate piers and wicket gate restrict flow there is less tendency for catapult. Thus, the intake gate with the greatest restrictions should be used for watering-up. It is possible that a long downstream penstock would cause greater uplift forces, but this was not proved in this study.
- e. A back-of-gate orifice configuration like that designed for Clarence Cannon powerhouse is very beneficial in reducing uplift forces with small gate openings required for watering-up.

47. Because of the interest in the catapulting phenomenon and the need for frequent demonstration to visiting engineers, two 1:100-scale models (Figure 8) were constructed to approximate a typical 12-in.-wide back-of-gate orifice design that could catapult and the Clarence Cannon back-of-gate orifice design that would not catapult. It was found that these rather simple and small models demonstrated the phenomenon satisfactorily and indicated that relatively simple and small models could be used in future investigations of either existing or proposed power intake gates. Obviously sufficient detail should be reproduced. The subject study demonstrated the capability of physical models to investigate and define acceptable and unacceptable designs and operations relative to "watering-up" procedures with power intake gates.

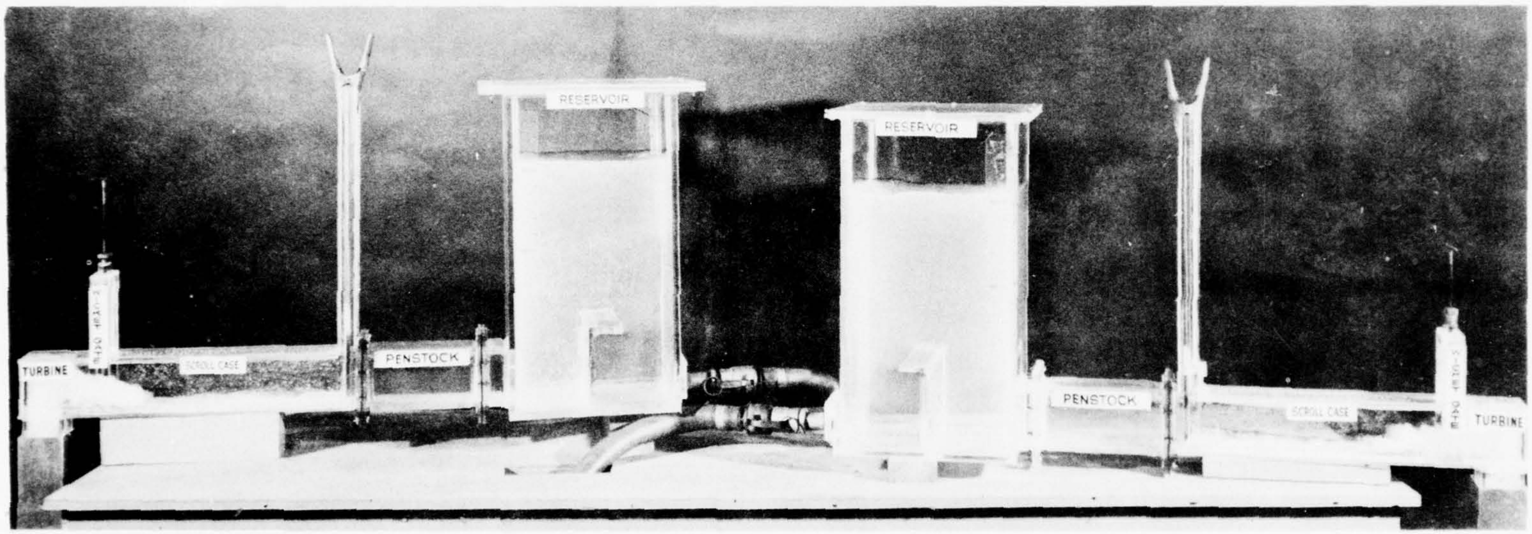


Figure 8. Two 1:100-scale models reproducing a simplified version of a powerhouse structure; the model on the left was constructed with a typical 12-in. back-of-gate orifice and the one on the right with the Clarence Cannon back-of-gate orifice design

Table 1

Catapult Heights, Big Bend Conditions

8.6875-in. Back-of-Gate Orifice

Gate Opening ft	Catapult Heights, ft, at Initial Heads of 96 ft	120 ft	140 ft
	Gate 110,000 lb, Dry Weight		
0.5	0	0	0
1.0	0	0.10	0
1.5	0	--	0
2.0	0.10	0.20	0.20
2.5	0.30	--	0.80
3.0	0.40	19	26
4.0	10.0	44.8	44.8
5.0	32.0	--	--
	Gate 137,000 lb, Dry Weight		
0.5	0	0	0
1.0	0	0	0
1.5	0	0	0
2.0	0	0	0
2.5	0.10	0.10	0.20
3.0	0.20	0.20	15.0
3.5	0.50	3.2	--
4.0	0.60	--	30.0
	Gate 150,000 lb, Dry Weight		
0.5	0	0	0
1.0	0	0	0
1.5	0	0	0
2.0	0	0	0
2.5	0.05	0.10	0.20
3.0	0.10	0.20	0.30
3.5	0.20	0.30	0.80
4.0	0.30	0.80	12.0
4.5	0.30	--	--
5.0	0.40	11.2	30.4

Table 2

Catapult Heights, Stockton Conditions

6.625-in. Back-of-Gate Orifice

Gate Opening ft	Catapult Heights, ft, at Initial Heads of		
	100 ft	120 ft	140 ft
0.5	0.0	0.0	0.0
0.5	0.0	0.0	0.0
1.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0
1.5	0.0	0.0	0.08
1.5	0.0	0.0	--
2.0	0.0	0.08	0.16
2.0	0.0	0.08	--
2.5	0.16	0.64	11.2
2.5	0.16	0.48	--
3.0	0.32	8.8	14.4
3.0	0.96	9.6	--
3.5	11.2	10.72	--
3.5	8.0	10.40	--
4.0	12.00	11.20	--
4.0	12.48	11.20	--

Note: Dry weight of gate = 131 kips.

Table 3

Uplift Forces and Pressures, Stockton Dam, 6.625-in. Back-of-Gate Orifice, Rigid Connection, Left Bay

Gate Opening ft	Maximum Uplift Force, kips	Feet of Water: Head Pool	Feet of Water: Pressure on Left Bay Invert	Feet of Water: Pressure on Bottom of Gate	Feet of Water: Scroll Case Pressure Just Before Maximum Uplift	Feet of Water: Scroll Case Pressure at Maximum Uplift
			80-ft Initial Head			
0.5	50.7	80.3	38.7	40.1	31.5	31.5
0.5	54.3	81.0	38.7	37.9	33.7	33.7
1.0	92.0	82.0	39.5	45.8	38.9	37.8
1.0	96.8	82.4	39.5	45.8	43.0	42.6
1.0	86.1	82.0	38.8	45.1	38.2	41.5
1.5	106.2	82.4	39.5	51.8	49.2	46.3
1.5	112.2	83.5	39.5	52.2	48.8	47.0
2.0	115.5	82.8	38.0	54.6	49.2	45.5
2.0	115.5	83.1	35.4	52.7	49.2	44.0
2.5	143.9	83.1	34.0	57.6	52.9	45.9
2.5	135.7	84.2	35.4	58.0	54.0	51.8
3.0	138.0	84.6	30.8	58.5	57.0	45.9
3.0	143.8	86.1	34.0	56.7	55.9	49.6
3.5	172.0	87.2	35.4	63.1	55.9	44.0
3.5	188.8	89.0	38.0	62.7	65.8	46.6
4.0	204.0	88.3	39.5	65.8	67.7	45.5
4.0	207.7	86.8	41.0	66.9	63.6	44.8
4.5	246.6	92.0	43.6	73.3	70.3	50.0
4.5	234.7	91.2	45.0	68.1	67.3	48.8
4.5	207.6	87.2	37.3	58.2	62.9	51.4
5.0	259.7	89.8	35.4	62.4	68.0	48.1
5.0	272.4	92.0	45.0	71.2	74.7	45.5
			100-ft Initial Head			
0.5	55.4	101.2	42.1	46.0	36.0	36.3
0.5	49.4	101.1	38.4	41.6	35.0	35.4
1.0	95.0	101.2	45.2	50.2	45.7	45.5
1.0	103.6	99.4	42.8	48.4	38.0	43.7
1.0	93.8	99.4	44.3	49.1	45.4	44.8
1.5	127.8	102.7	42.8	56.3	49.0	51.4
1.5	118.0	101.6	32.5	46.7	49.8	37.4
2.0	131.9	99.7	35.4	51.2	56.4	47.0
2.0	131.9	102.3	43.6	60.5	56.7	51.1
2.5	186.8	102.0	43.6	72.0	64.4	61.4
2.5	165.0	98.6	33.1	59.4	60.4	45.7
3.0	188.0	103.4	36.9	68.1	58.2	45.2
3.0	213.0	100.8	38.4	76.2	61.1	58.1
3.5	230.2	105.3	41.3	76.4	70.3	47.7
3.5	238.4	107.1	44.3	81.9	60.0	48.1
4.0	266.2	112.7	49.1	90.2	75.8	47.0
4.0	247.0	111.9	49.1	88.3	67.0	50.0
4.5	345.7	112.7	52.0	98.0	83.9	49.6
4.5	387.9	111.9	46.5	90.6	79.8	56.6
5.0	515.3	113.0	53.5	96.7	81.7	62.9
5.0	530.0	120.0	59.4	107.8	81.7	62.9
			120-ft Initial Head			
0.5	60.8	120.9	42.1	42.4	38.5	38.16
0.5	63.3	120.7	42.1	42.5	39.6	39.63
1.0	103.2	120.1	45.0	51.0	45.9	45.9
1.0	118.0	121.2	48.7	53.6	51.45	51.1
1.5	126.6	119.3	50.2	57.4	53.7	49.6
1.5	116.7	122.6	46.5	61.8	59.6	54.8
2.0	161.8	121.9	45.0	69.3	59.6	59.9
2.0	163.0	121.9	48.7	56.0	64.7	40.7
2.5	172.8	122.6	44.3	74.2	63.6	57.3
2.5	200.7	123.4	42.8	68.4	67.7	50.3
2.5	267.5	117.8	45.0	80.9	70.6	60.7
3.0	342.0	125.2	44.3	81.0	82.1	54.8
3.0	324.8	126.0	44.3	75.9	78.4	54.4
3.0	323.6	123.7	43.6	79.2	78.8	59.6
3.5	333.4	123.4	48.0	87.8	82.4	54.8
3.5	322.4	124.5	48.0	85.6	79.9	49.6
4.0	463.7	131.5	51.7	93.8	86.9	52.9
4.0	379.7	127.4	44.3	85.4	89.8	61.0
4.5	470.6	137.8	61.3	111.7	97.9	71.4
4.5	581.6	133.0	58.3	100.2	97.2	75.9
5.0	627.7	140.7	59.8	108.9	106.4	74.7
5.0	553.4	138.9	56.8	116.2	98.3	71.4

Note: All pressures are referenced to the left bay invert and were measured at time maximum uplift occurred.

Table 4

Uplift Forces and Pressures, Big Bend Dam, 8.6875-in.

Back-of-Gate Orifice, Rigid Connection, Left Bay

Gate Opening ft	Maximum Uplift Force, kips	Feet of Water				
		Head Pool	Pressure on Left Bay Invert	Pressure on Bottom of Gate	Scroll Case Pressure Just Before Maximum Uplift	Scroll Case Pressure at Maximum Uplift
			80-ft Initial Head			
0.5	36.9	81.7	38.0	35.4	24.4	24.4
0.5	43.0	82.4	38.7	38.1	28.1	31.5
1.0	95.8	82.4	48.0	41.4	32.1	38.1
1.0	87.2	82.4	46.6	38.6	32.9	38.1
1.5	110.6	83.2	54.4	47.3	42.6	44.2
1.5	110.6	82.4	55.2	47.3	44.6	43.8
2.0	116.7	83.2	58.0	48.7	52.2	49.0
2.0	113.0	84.6	58.8	48.7	56.2	56.6
2.5	135.2	85.7	67.3	57.4	66.7	60.7
2.5	127.8	84.6	63.8	51.9	65.9	59.5
3.0	127.8	83.9	65.9	57.8	60.7	62.3
3.0	129.0	85.7	68.1	57.8	60.7	59.9
3.5	145.0	85.7	70.9	60.2	62.3	66.3
3.5	148.7	84.6	68.1	52.9	62.3	51.0
4.0	159.7	85.7	68.8	55.2	72.4	49.8
4.0	143.8	86.5	70.9	55.2	63.9	53.0
4.5	162.2	85.7	74.5	60.5	63.9	54.2
4.5	152.4	84.6	64.5	50.3	70.3	38.1
5.0	202.8	88.0	79.5	65.3	72.8	51.8
5.0	220.0	90.5	80.2	66.2	80.8	51.4
			100-ft Initial Head			
0.5	44.2	103.8	42.6	38.1	24.0	26.1
0.5	43.0	101.6	40.4	37.2	27.3	28.1
1.0	84.7	103.1	52.2	42.2	32.5	40.2
1.0	85.9	103.8	52.2	43.1	40.2	38.3
1.5	119.3	102.4	63.2	49.1	44.6	45.4
1.5	116.9	103.8	65.4	50.0	39.8	48.6
2.0	128.9	103.1	70.6	54.1	54.2	48.6
2.0	131.2	102.4	73.5	57.8	57.9	53.0
2.5	138.4	102.4	75.7	58.3	58.3	55.8
2.5	136.0	105.7	80.1	59.2	55.8	52.6
3.0	145.6	103.8	81.6	66.0	63.1	60.7
3.0	145.6	103.8	80.8	58.8	58.3	49.0
3.5	174.2	109.8	91.9	72.9	72.8	69.5
3.5	168.1	105.0	88.9	72.9	73.2	69.5
4.0	186.1	105.0	91.9	76.1	80.0	76.4
4.0	180.2	109.8	94.1	77.9	77.2	74.4
4.5	247.0	110.5	95.5	73.9	68.3	50.2
4.5	250.6	106.4	96.3	75.7	67.9	57.5
5.0	232.7	111.6	102.9	74.4	70.3	69.5
5.0	298.3	109.8	99.2	77.1	72.4	61.1
			120-ft Initial Head			
0.5	39.7	120.7	47.5	38.4	33.1	33.1
0.5	39.7	120.7	47.5	38.4	33.6	33.6
1.0	86.7	120.8	56.9	40.7	36.6	40.4
1.0	93.9	121.6	60.5	46.5	45.1	42.6
1.5	114.4	121.6	72.0	51.0	46.8	46.0
1.5	118.0	121.9	72.0	51.9	55.8	53.3
2.0	143.3	123.0	86.4	62.2	54.6	62.7
2.0	132.5	123.8	81.4	56.9	61.0	56.7
2.5	142.1	123.0	93.6	67.2	70.0	63.6
2.5	154.1	123.8	92.9	66.3	65.7	61.0
3.0	209.6	119.7	97.2	72.2	84.5	75.5
3.0	224.0	120.8	95.8	71.3	77.3	67.4
3.5	210.7	124.5	106.6	78.0	78.5	73.8
3.5	251.7	124.5	104.4	80.7	86.7	79.4
4.0	234.8	130.4	114.5	92.8	87.1	84.0
4.0	252.9	127.8	113.8	90.2	94.0	88.8
4.5	298.6	129.3	115.2	83.5	91.0	67.4
4.5	298.6	128.6	110.2	81.7	--	62.3
5.0	281.8	132.6	115.2	91.2	92.7	81.9
5.0	296.2	126.4	115.2	86.7	86.7	91.4

Note: All pressures are referenced to the left bay invert and were measured at time maximum uplift occurred.

Table 5

Uplift Forces and Pressures, 12-in. Back-of-Gate Orifice

Rigid Connection, Left Bay

Gate Opening ft	Maximum Uplift Force, kips	Feet of Water: Head Pool	Pressure on Left Bay Invert	Pressure on Bottom of Gate	Scroll Case Pressure Just Before Maximum Uplift	Scroll Case Pressure at Maximum Uplift
			80-ft Initial Head			
1.0	85.2	78.4	47.9	--	27.0	28.4
1.0	84.6	79.2	46.5	--	27.0	27.0
1.0	82.2	80.1	46.5	--	26.3	26.6
2.0	113.2	81.8	66.0	--	42.6	42.9
2.0	100.1	82.0	68.7	--	45.8	43.6
2.0	107.3	81.0	61.8	--	36.9	36.9
3.0	116.8	79.2	68.7	--	45.8	40.8
3.0	124.0	81.0	66.0	--	44.0	37.3
3.0	114.4	82.7	69.4	--	43.3	44.7
4.0	137.1	82.7	71.5	--	50.7	44.7
4.0	127.5	81.0	70.8	--	48.3	44.4
4.0	129.9	82.7	70.8	--	51.8	37.3
5.0	147.8	85.3	76.4	--	54.6	47.9
5.0	153.8	84.5	76.4	--	55.7	41.5
5.0	166.9	85.3	76.4	--	44.4	35.1
			100-ft Initial Head			
1.0	87.0	101.0	49.3	--	28.4	27.0
1.0	84.6	100.0	52.1	--	31.2	30.2
1.0	85.8	101.0	50.7	--	27.3	31.6
2.0	110.8	101.9	68.0	--	30.9	42.2
2.0	118.0	102.8	69.4	--	44.4	41.2
2.0	119.2	102.3	66.6	--	36.6	40.5
3.0	127.5	102.8	78.4	--	51.4	46.1
3.0	144.2	101.0	76.4	--	49.7	41.5
3.0	129.9	103.6	80.5	--	51.4	49.7
4.0	162.1	102.8	83.3	--	55.4	51.4
4.0	184.8	103.6	88.7	--	58.5	55.7
4.0	172.8	106.2	84.7	--	54.6	40.8
5.0	219.3	109.7	94.4	--	62.4	42.9
5.0	180.0	108.0	88.9	--	56.8	46.1
5.0	185.9	106.2	91.6	--	67.0	60.7
			120-ft Initial Head			
1.0	92.2	121.6	61.1	56.2	46.4	42.8
1.0	95.8	122.3	54.2	48.0	37.7	37.7
1.0	104.4	122.3	61.8	57.6	45.7	44.6
2.0	127.8	122.3	76.4	60.9	49.7	45.7
2.0	131.5	122.3	77.8	--	52.2	52.2
2.0	116.7	124.7	78.4	--	46.8	48.6
3.0	147.5	126.2	92.3	--	52.2	57.6
3.0	164.7	125.2	90.2	--	63.0	55.8
3.0	169.6	123.7	90.2	--	60.9	53.6
4.0	195.4	125.8	103.4	83.5	70.3	63.0
4.0	196.6	125.8	102.8	--	78.8	64.5
4.0	184.3	128.0	97.9	86.5	74.3	45.0
5.0	235.9	125.2	111.1	--	83.3	72.5
5.0	235.9	122.3	107.6	--	83.3	76.4
5.0	243.3	126.6	111.1	--	84.8	77.2

Note: All pressures are referenced to the left bay invert and were measured at the time maximum uplift occurred.

Table 6

Uplift Forces and Pressures, Clarence Cannon Dam, 71.63-in.

Back-of-Gate Orifice, Rigid Connection, Left Bay

		Feet of Water			
Gate Opening ft	Maximum Uplift Force kips	Head Pool	Pressure on Left Bay Invert	Pressure on Bottom of Gate	Scroll Case Pressure at Maximum Uplift
			50-ft Initial Head		
0.5	30.7	49.2	43.0	46.4	26.8
0.5	26.0	48.4	46.5	49.8	31.1
1.0	60.2	49.9	38.9	42.0	23.2
1.0	63.1	48.4	41.0	44.2	26.8
1.5	59.0	50.3	42.4	45.3	30.4
1.5	59.0	49.2	41.0	43.6	26.8
2.0	59.0	49.2	43.7	43.8	30.4
2.0	60.2	49.2	42.4	43.1	30.4
2.5	59.0	49.9	43.7	43.6	31.1
2.5	60.2	47.7	44.4	43.6	32.6
3.0	57.8	48.4	45.8	45.5	34.7
3.0	63.7	50.3	46.5	45.5	34.0
3.5	59.0	49.2	48.5	47.3	36.9
3.5	59.0	49.2	47.1	46.0	37.6
4.0	57.8	48.4	47.1	46.1	34.7
4.0	53.1	49.2	45.8	45.1	31.8
4.5	60.2	50.3	47.8	47.0	37.6
4.5	50.7	47.7	47.8	47.0	36.9
5.0	61.4	49.2	48.5	46.8	36.2
5.0	61.4	50.3	50.6	50.2	41.2
5.5	70.8	51.0	48.5	46.6	34.7
5.5	60.2	49.2	50.6	49.3	42.6
6.0	70.8	49.2	51.9	51.9	41.9
6.0	67.3	49.2	48.5	47.8	37.6
6.5	73.2	50.3	52.6	52.4	41.2
6.5	63.7	50.3	51.2	51.7	41.2
7.0	55.5	48.4	51.2	50.2	41.2
7.0	55.5	49.2	51.2	50.2	41.2
			80-ft Initial Head		
0.5	47.7	80.0	42.0	38.9	41.7
0.5	48.9	80.3	49.9	47.4	49.5
0.5	42.2	81.1	42.6	36.0	40.0
0.5	42.2	80.0	43.3	36.4	40.0
0.5	41.0	81.8	43.3	36.6	41.5
1.0	62.0	80.3	48.5	42.2	44.5
1.0	68.0	80.3	49.2	43.6	45.2

(Continued)

Note: All pressures are referenced to the left bay invert and were measured at the time maximum uplift force occurred.

Table 6 (Continued)

Gate Opening ft	Maximum Uplift Force kips	Feet of Water: Head Pool	Feet of Water: Pressure on Left Bay Invert	Feet of Water: Pressure on Bottom of Gate	Feet of Water: Scroll Case Pressure at Maximum Uplift
		80-ft Initial Head (Continued)			
1.0	66.2	81.8	50.2	40.6	44.4
1.0	66.2	81.1	49.6	39.9	43.6
1.0	66.2	80.3	50.2	40.6	44.4
1.0	44.9	82.1	53.0	45.5	45.2
1.0	36.4	81.6	59.8	46.2	45.9
1.5	59.0	81.8	59.3	45.3	50.2
1.5	55.4	81.4	62.5	48.8	53.8
1.5	51.8	81.8	62.8	50.2	53.8
1.5	73.9	80.3	53.4	44.5	44.5
1.5	65.6	80.7	57.0	48.4	50.2
2.0	42.3	82.1	61.2	45.1	51.6
2.0	45.8	82.1	62.5	48.6	53.1
2.0	48.2	82.9	68.4	52.8	59.6
2.0	45.8	81.8	62.8	45.1	52.4
2.0	42.2	81.8	64.2	47.2	53.8
2.5	49.4	82.2	67.0	47.0	54.6
2.5	49.4	83.3	69.8	51.2	59.3
2.5	60.2	82.9	70.5	52.6	58.9
2.5	65.6	80.3	59.9	45.8	51.6
2.5	47.7	80.3	63.4	49.4	52.4
3.0	65.6	81.1	70.6	56.9	59.5
3.0	56.0	80.7	64.9	50.6	54.5
3.0	66.2	82.9	68.4	48.2	53.1
3.0	61.4	81.8	68.4	48.2	53.8
3.0	55.4	82.2	71.9	53.1	58.2
3.0	69.4	84.2	68.0	51.4	58.0
3.0	63.5	83.2	68.6	51.7	60.9
3.5	57.2	82.6	71.3	57.4	60.2
3.5	63.2	80.7	66.3	50.4	56.6
3.5	71.1	82.2	69.8	48.0	55.3
3.5	72.2	83.3	76.1	57.1	59.6
3.5	72.2	82.2	71.2	50.1	53.1
4.0	63.2	81.4	69.8	54.4	58.4
4.0	63.2	80.3	68.4	53.0	58.0
4.0	65.0	82.2	71.2	49.2	56.7
4.0	66.2	82.9	70.5	47.1	56.0
4.0	65.0	83.3	71.9	48.5	58.9
4.0	74.1	84.2	74.7	58.3	63.8
4.0	69.4	84.5	68.6	50.6	58.8
4.5	62.6	82.9	78.2	60.2	67.6
4.5	73.4	82.2	76.4	55.0	59.6
4.5	55.4	83.3	76.8	56.0	61.8
4.5	66.8	81.8	74.8	61.2	64.5
4.5	68.0	81.4	69.1	50.0	53.8
5.0	85.8	85.8	80.9	64.2	73.0
5.0	81.1	83.7	73.4	55.1	65.2

(Continued)

Table 6 (Continued)

Gate Opening ft	Maximum Uplift Force kips	Feet of Water: Head Pool	Pressure on Left Bay Invert	Pressure on Bottom of Gate	Scroll Case Pressure at Maximum Uplift
		80-ft Initial Head (Continued)			
5.0	72.2	84.4	81.0	62.1	67.6
5.0	84.3	85.1	83.8	65.6	70.6
5.0	77.1	84.8	87.4	62.1	69.8
5.0	71.6	82.9	78.4	65.2	71.6
5.0	77.5	82.9	78.4	65.2	66.2
5.5	69.4	85.3	74.7	55.6	64.5
5.5	72.9	86.3	81.5	64.7	73.7
6.0	94.0	86.8	87.6	75.6	79.8
6.0	80.0	86.3	81.5	63.8	69.4
6.5	95.2	86.3	84.2	69.9	77.3
6.5	97.6	86.8	88.3	76.2	83.7
7.0	101.1	86.3	85.6	66.9	75.2
7.0	103.5	86.8	84.2	66.9	76.6
		100-ft Initial Head			
0.5	50.6	101.0	41.9	35.8	37.9
0.5	54.2	101.0	41.9	36.5	40.7
0.5	48.2	101.0	41.2	34.4	39.3
0.5	62.6	100.6	49.4	36.0	38.6
0.5	68.8	100.3	49.4	36.6	39.3
1.0	34.9	102.1	63.0	49.0	52.4
1.0	28.2	101.7	53.7	44.1	51.6
1.0	36.1	101.0	62.1	50.8	54.8
1.0	47.0	101.0	62.8	51.9	54.8
1.0	39.7	101.0	57.9	46.2	50.9
1.5	41.0	103.2	75.2	57.2	61.8
1.5	26.5	101.0	66.3	49.6	55.5
1.5	24.1	101.4	64.2	48.8	55.5
1.5	24.1	101.4	69.4	53.1	58.3
2.0	30.1	102.9	77.5	60.0	64.0
2.0	24.1	102.9	74.0	52.9	58.3
2.0	24.1	101.4	69.8	47.9	54.8
2.0	38.5	102.5	73.8	52.1	58.9
2.0	29.4	101.3	69.3	49.3	55.9
2.5	38.5	102.9	78.1	52.4	61.1
2.5	36.1	103.6	77.5	54.1	64.0
2.5	33.7	98.8	78.2	56.9	59.0
2.5	44.6	102.9	76.8	53.4	62.6
3.0	44.6	103.6	78.2	53.5	60.4
3.0	36.1	102.1	76.4	48.9	56.9
3.0	39.7	101.8	73.3	45.4	54.8
3.0	45.8	103.9	78.5	54.5	63.0
3.0	57.6	103.0	78.1	55.2	65.2
3.0	48.2	102.9	78.8	46.6	56.0

(Continued)

Table 6 (Continued)

		Feet of Water			
Gate Opening ft	Maximum Uplift Force kips	Head Pool	Pressure on Left Bay Invert	Pressure on Bottom of Gate	Scroll Case Pressure at Maximum Uplift
		100-ft Initial Head (Continued)			
3.5	73.4	102.9	81.7	53.6	62.6
3.5	71.1	106.9	92.4	68.3	74.2
3.5	54.2	103.6	75.4	47.3	56.2
3.5	42.2	99.9	76.1	53.7	58.3
3.5	50.6	102.5	78.2	50.8	59.0
4.0	66.2	102.5	80.3	53.5	62.6
4.0	72.2	101.8	80.3	52.0	61.8
4.0	65.0	101.4	78.2	49.2	58.3
4.0	70.5	105.2	89.0	68.1	73.0
4.0	69.4	108.2	93.1	71.6	80.9
4.0	72.2	102.9	82.4	50.6	58.9
4.0	69.8	102.9	85.2	53.8	64.7
4.5	53.0	104.7	97.7	78.1	85.1
4.5	60.2	104.7	90.7	68.1	79.5
4.5	66.2	103.6	84.4	56.1	58.3
4.5	75.9	106.2	92.4	66.5	71.3
4.5	72.2	104.7	86.0	57.4	64.7
5.0	84.3	106.6	96.7	71.2	81.5
5.0	87.9	105.1	97.4	76.0	85.1
5.0	84.3	103.6	90.7	65.1	72.4
5.0	75.9	104.7	92.1	67.2	76.0
5.0	81.9	105.4	98.4	80.0	88.6
5.0	81.1	105.6	89.7	64.9	73.0
5.0	76.4	103.9	80.9	52.3	60.9
5.5	84.6	106.9	99.2	75.8	87.3
5.5	84.6	104.3	92.4	67.5	76.6
6.0	107.0	109.4	104.6	81.9	88.7
6.0	94.0	107.7	96.5	73.6	85.8
6.5	111.7	106.4	95.3	72.0	80.1
6.5	111.7	108.2	102.6	79.6	90.1
7.0	135.2	104.7	102.6	85.7	92.3
7.0	140.0	108.6	101.9	81.5	90.8
		120-ft Initial Head			
0.5	25.3	120.2	44.4	36.6	43.6
0.5	42.2	121.0	41.2	35.8	39.3
0.5	41.0	121.0	41.9	36.5	49.2
0.5	36.1	120.6	41.9	35.1	39.3
1.0	28.9	120.2	60.0	48.3	52.7
1.0	18.1	120.2	55.8	43.4	49.9
1.0	19.3	120.6	64.2	52.6	58.3
1.0	47.0	121.8	60.5	47.6	60.9
1.0	41.2	121.4	61.2	49.7	60.9

(Continued)

Table 6 (Concluded)

Gate Opening ft	Maximum Uplift Force kips	Head Pool	Pressure on Left Bay Invert	Pressure on Bottom of Gate	Scroll Case Pressure at Maximum Uplift
		Feet of Water			
		120-ft Initial Head (Continued)			
1.5	21.7	119.1	83.0	65.1	68.9
1.5	10.8	120.2	76.8	58.0	64.7
1.5	12.0	119.5	77.5	59.5	65.4
2.0	30.1	121.0	84.4	60.0	65.4
2.0	12.0	120.6	86.5	63.5	71.7
2.0	18.1	119.8	83.8	58.6	65.4
2.0	35.3	121.4	77.5	53.5	68.0
2.0	35.3	121.8	78.8	56.3	68.7
2.0	19.2	121.3	78.8	50.7	58.9
2.5	36.1	121.0	84.5	54.0	59.6
2.5	38.5	121.3	85.2	53.3	53.8
2.5	25.3	119.1	78.2	46.3	51.3
2.5	37.3	121.3	87.9	60.5	65.5
2.5	33.7	121.0	87.9	61.2	68.2
3.0	24.1	119.5	83.8	50.3	61.1
3.0	30.1	120.2	83.8	51.0	61.8
3.0	28.9	122.1	87.9	58.1	71.7
3.0	47.0	121.0	84.9	56.6	76.6
3.0	47.0	121.0	84.9	56.6	70.9
3.0	34.9	121.7	86.7	56.6	63.3
3.0	33.7	121.0	86.0	52.4	66.2
3.5	48.2	123.2	93.1	61.3	71.3
3.5	36.1	123.2	97.0	68.6	71.7
3.5	32.5	122.4	97.7	65.0	76.0
3.5	44.6	121.0	87.9	54.4	64.7
4.0	48.2	121.3	92.8	58.4	61.5
4.0	51.8	122.8	92.8	59.1	71.7
4.0	54.2	122.4	85.2	51.3	62.6
4.0	58.8	119.5	94.4	64.6	79.8
4.0	58.8	119.5	89.0	58.3	73.0
4.0	63.8	123.6	90.3	54.8	65.5
4.0	51.8	122.8	93.8	57.6	61.8
4.5	48.2	123.2	93.5	62.5	69.6
4.5	48.2	119.1	93.5	57.2	68.9
4.5	54.2	123.6	99.8	68.1	73.1
4.5	75.9	121.7	98.9	63.0	72.7
4.5	65.0	123.2	93.1	57.4	64.0
5.0	72.2	121.7	98.2	63.5	71.3
5.0	69.8	123.2	106.0	75.4	85.1
5.0	74.9	122.8	105.4	73.6	85.8
5.0	84.3	125.0	120.7	101.3	106.3
5.0	70.5	119.9	95.8	64.9	84.4
5.0	85.8	121.8	95.1	63.5	79.4
5.5	70.5	121.0	95.1	60.5	80.1
5.5	70.5	123.6	101.9	72.4	87.3
6.0	88.2	119.5	101.9	68.7	75.9
6.0	95.2	124.4	104.6	71.5	87.3

(Sheet 5 of 5)

Table 7

Stockton Dam, Maximum Uplift Forces Measured in Right Bay (Looking Downstream), 6.625-in. Back-of-Gate Orifice

Gate Opening ft	Maximum Uplift Force, kips, at Initial Head of 100 ft	120 ft
0.5	80.6	77.4
0.5	73.7	77.4
1.0	86.0	79.9
1.0	76.2	76.8
1.5	95.8	89.7
1.5	92.2	87.2
2.0	95.8	121.6
2.0	82.9	118.0
2.5	97.1	135.2
2.5	111.8	129.0
3.0	120.4	159.7
3.0	118.0	127.8
3.5	164.7	147.5
3.5	133.9	161.0
4.0	192.9	124.1
4.0	135.2	163.4

Table 8

Big Bend Dam, Maximum Uplift Forces Measured in

Middle Bay, 8.6875-in. Back-of-Gate Orifice

Gate Opening ft	Maximum Uplift Force, kips, at Initial Head of 80 ft	100 ft	120 ft
0.5	42.9	23.8	17.9
0.5	--	--	21.5
0.75	52.5	21.5	16.7
0.75	68.0	35.8	22.6
0.75	--	--	28.6
0.75	--	--	27.4
1.0	87.0	69.1	68.0
1.0	87.0	69.1	48.9
1.5	109.7	113.2	87.0
1.5	115.7	108.5	99.0
2.0	126.4	136.0	128.8
2.0	128.4	138.3	172.9
2.5	150.2	166.9	159.8
2.5	138.3	153.8	175.3
3.0	122.8	157.4	231.3
3.0	131.2	131.2	189.6
3.5	146.7	159.8	217.0
3.5	149.0	164.5	192.0
4.0	155.0	158.6	274.2
4.0	152.6	190.8	270.7
4.5	178.9	236.1	473.4
4.5	183.6	316.0	261.1
4.5	--	--	251.6
5.0	166.9	258.7	479.3
5.0	165.7	379.2	523.4

Table 9

Big Bend Dam, Maximum Uplift Forces Measured in Middle Bay, 8.6875-in. Back-of-Gate Orifice

Gate Opening ft	80-ft Initial Head, Maximum Uplift Force, kips			
	Left Gate Slot Sealed	Right Gate Slot Sealed	Right & Left Gate Slots Sealed	All Gate Slots Opened
0.5	44.1	59.6	70.3	42.9
0.5	58.4	56.0	78.7	--
0.75	83.5	78.7	81.1	52.5
0.75	75.1	58.4	119.2	68.0
1.0	103.6	84.3	116.9	87.0
1.0	90.3	70.3	125.2	87.0
1.5	122.8	108.4	150.5	109.7
1.5	137.3	106.0	142.1	115.7

Table 10

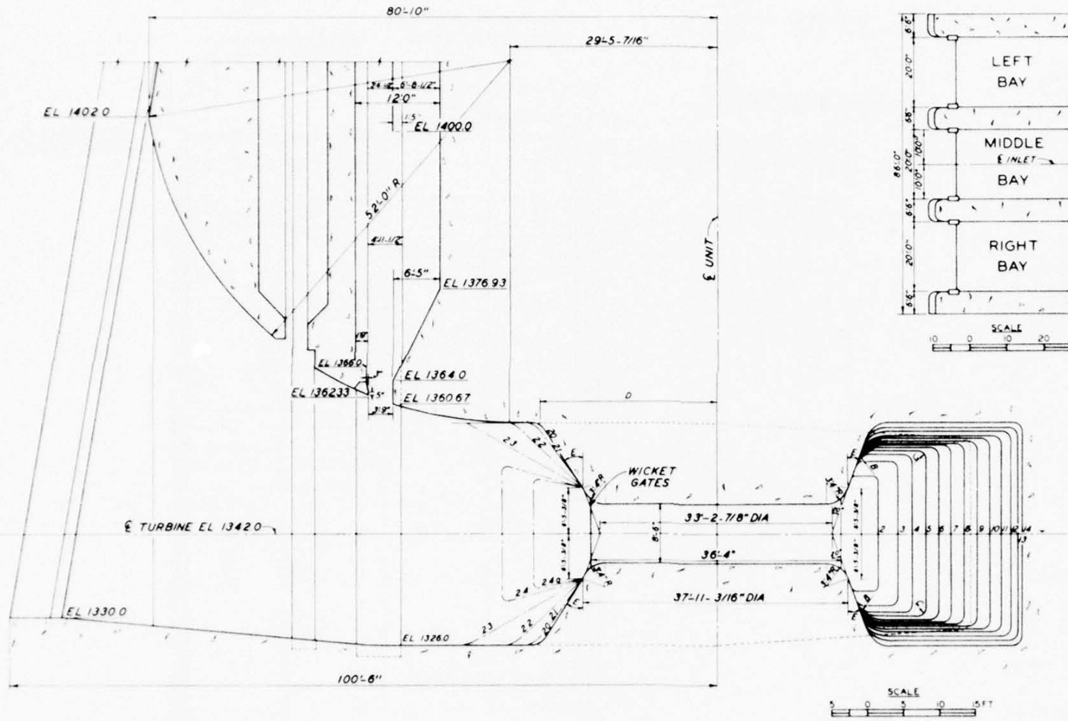
Stockton Dam, Maximum Uplift Forces Measured with and Without Skin Plate on Downstream Side of Intake Gate in Left Bay, 6.625-in. Back-of-Gate Orifice

Gate Opening ft	Maximum Uplift Force, kips			
	100-ft Initial Head		120-ft Initial Head	
	Without Skin Plate	With Skin Plate	Without Skin Plate	With Skin Plate
1.0	95.0	101.2	103.2	104.8
1.0	103.6	107.2	118.0	138.5
1.0	93.8	--	--	--
2.0	131.9	146.9	161.8	146.9
2.0	131.9	160.2	163.0	192.7
3.0	188.0	228.8	342.0	403.4
3.0	213.0	219.2	324.8	531.0
3.0	--	249.3	323.6	--
4.0	266.2	278.2	463.7	552.8
4.0	247.0	248.0	379.7	558.8
5.0	515.3	507.0	627.7	651.5
5.0	530.0	369.7	553.4	647.9
5.0	--	443.2	--	--

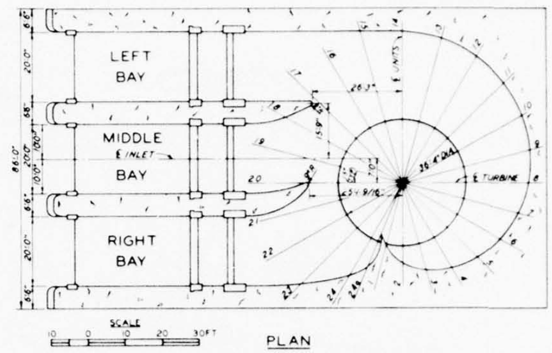
Table 11

Big Bend Dam, Maximum Uplift Forces for Long (124-ft) and Short (24-ft) Penstocks, 8.6875-in. Back-of-Gate Orifice, Left Bay (Looking Downstream)

Gate Opening ft	Maximum Uplift Force, kips					
	80-ft Initial Head		100-ft Initial Head		120-ft Initial Head	
	Short Penstock	Long Penstock	Short Penstock	Long Penstock	Short Penstock	Long Penstock
1.0	95.8	97.5	84.7	70.3	86.7	113.2
1.0	87.2	66.2	85.9	77.5	93.9	--
1.5	110.6	106.0	119.3	95.4	114.4	101.3
1.5	110.6	93.9	116.9	119.2	118.0	--
2.0	116.7	118.0	128.9	137.1	143.3	145.4
2.0	113.0	99.9	131.2	140.7	132.5	119.2
2.5	135.2	116.8	138.4	156.6	142.1	166.9
2.5	127.8	107.2	136.0	166.2	154.1	150.2
3.0	127.8	121.6	145.6	144.5	209.6	223.0
3.0	129.0	128.9	145.6	174.6	224.0	202.7
3.5	145.0	150.5	174.2	197.5	210.7	219.4
3.5	148.7	144.5	168.1	192.7	251.7	243.2
4.0	159.7	160.2	186.1	203.5	234.8	259.9
4.0	143.8	161.4	180.2	209.6	252.9	256.4
4.5	162.2	180.6	247.0	208.3	298.6	302.9
4.5	152.4	171.0	250.6	232.4	298.6	274.2
5.0	202.8	238.4	232.7	256.5	281.8	298.1
5.0	220.0	218.0	298.3	263.7	296.2	372.0



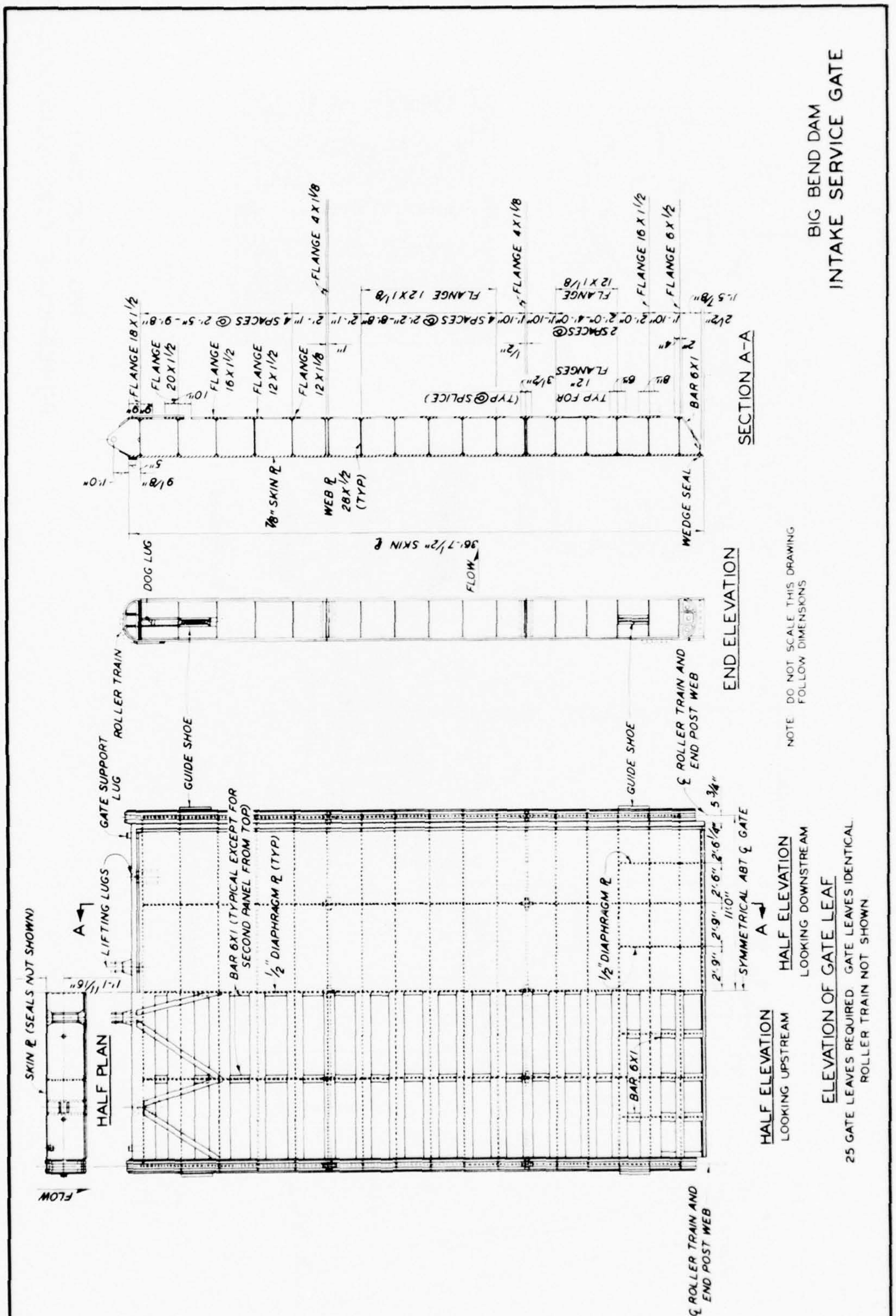
ELEVATION ALONG ℄ OF TURBINE



PLAN

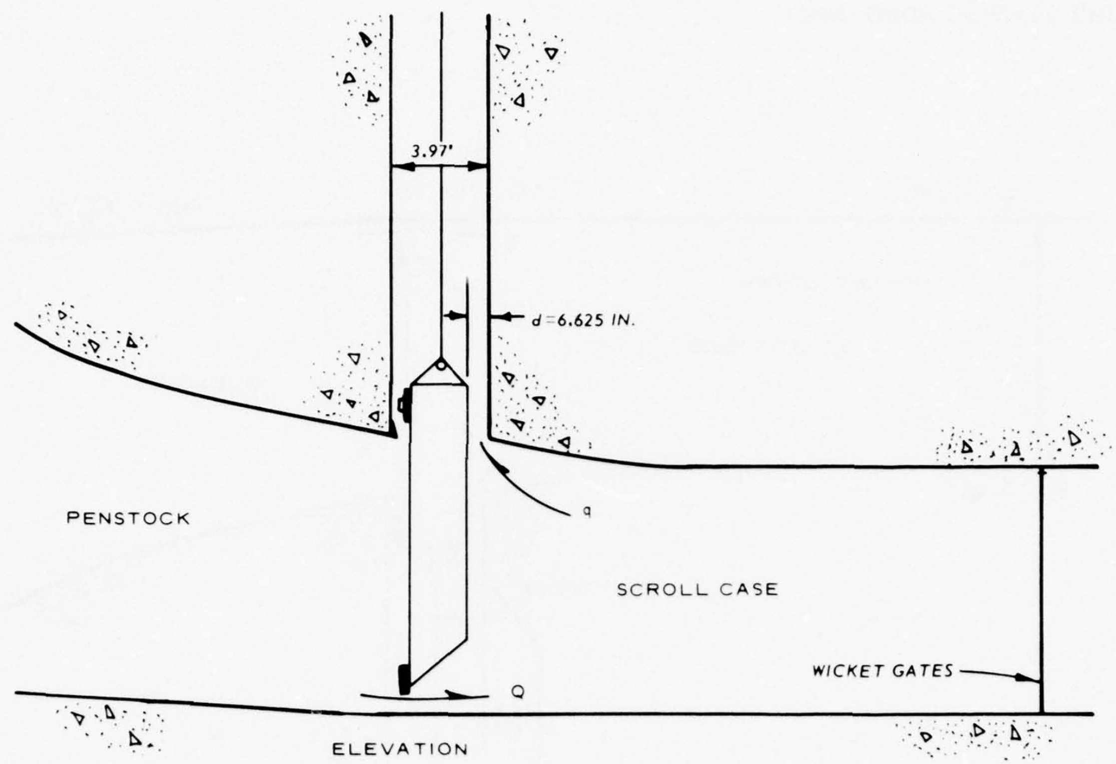
SECTION REF	A	RADIUS B	RADIUS C	D	ANGLE E
1					
2	16'-6"	6"	1'-0"	19'-7-15/32"	
3	20'-8"	1'-1"	1'-4"	20'-4-9/16"	20°
4	22'-8"	2'-2"	1'-4"	20'-8-15/16"	20°
5	23'-8"	2'-10-1/2"	1'-4"	20'-11-1/8"	20°
6	24'-8"	3'-4"	1'-4"	21'-1-9/32"	20°
7	25'-4"	3'-4"	1'-4"	21'-2-3/4"	20°
8	25'-10"	3'-4"	1'-4"	21'-3-27/32"	20°
9	26'-7"	3'-4"	1'-4"	21'-5-15/32"	20°
10	27'-4"	3'-4"	1'-4"	21'-7-1/8"	20°
11	28'-2"	3'-4"	1'-4"	21'-8-15/16"	20°
12	29'-4"	3'-4"	1'-4"	21'-11-1/2"	20°
13	30'-6"	3'-4"	1'-4"	22'-2-1/32"	20°
14	32'-0"	3'-4"	1'-4"	22'-5-5/16"	20°
15	32'-0"	3'-4"	1'-4"	22'-6-5/16"	20°26'
16	32'-0"	3'-4"	1'-4"	22'-9-3/8"	21°47'
17	32'-0"	3'-4"	-	23'-4-3/32"	24°36'
18	32'-0"	3'-4"	-	23'-8-23/32"	26°29'
19	32'-0"	3'-4"	-	24'-4-17/32"	29°32'
20	32'-0"	3'-4"	-	25'-1-1/8"	32°41'
21	32'-0"	3'-4"	-	26'-1-11/16"	36°55'
22	32'-0"	3'-4"	-	29'-1-7/8"	46°51'
23	32'-0"	3'-4"	-	35'-8-1/2"	60°18'
24	-	-	1'-4"	-	73°16'
24a	-	-	11"	-	78°36'

BIG BEND DAM
POWERHOUSE CONFIGURATION



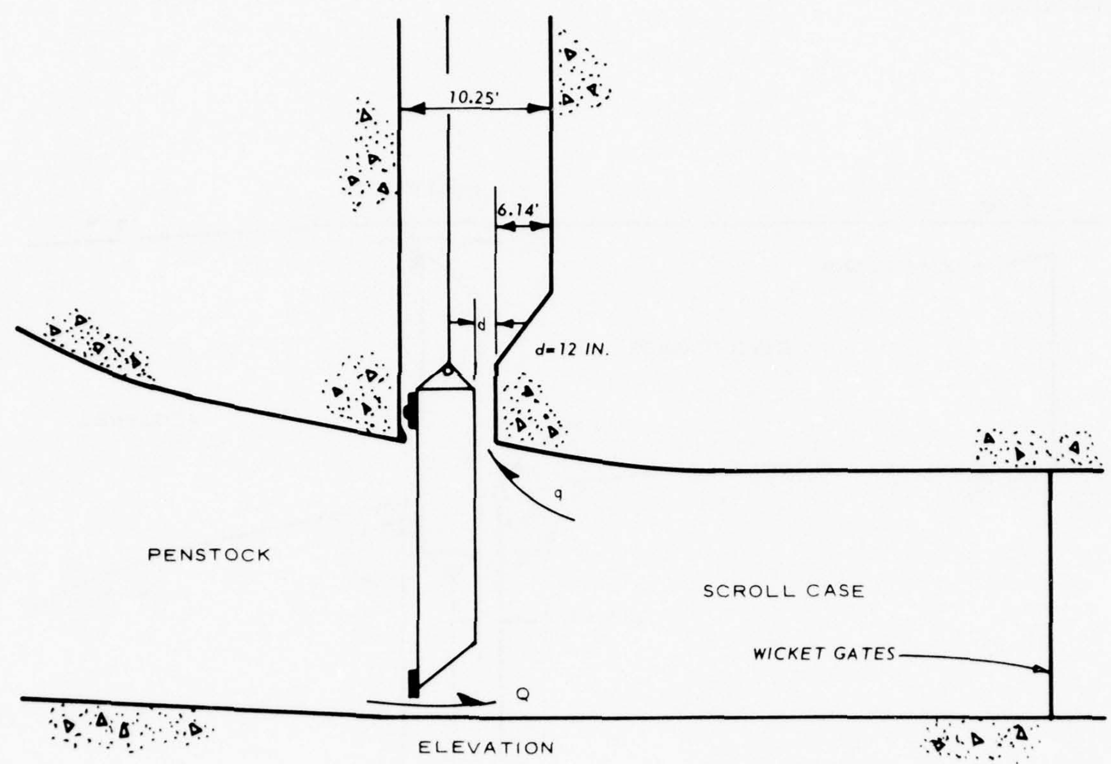
BIG BEND DAM
INTAKE SERVICE GATE
SECTION A-A
END ELEVATION
HALF PLAN
HALF ELEVATION
LOOKING UPSTREAM
HALF ELEVATION
LOOKING DOWNSTREAM
ELEVATION OF GATE LEAF
25 GATE LEAVES REQUIRED GATE LEAVES IDENTICAL.
ROLLER TRAIN NOT SHOWN
NOTE DO NOT SCALE THIS DRAWING
FOLLOW DIMENSIONS
SKIN ℞ (SEALS NOT SHOWN)
FLOW
LIFTING LUGS
GATE SUPPORT LUG
GUIDE SHOE
ROLLER TRAIN
DOG LUG
BAR 6X1 (TYPICAL EXCEPT FOR SECOND PANEL FROM TOP)
1/2" DIAPHRAGM ℞ (TYP)
1/2" DIAPHRAGM ℞
BAR 6X1
SYMMETRICAL ABT ℄ GATE
℄ ROLLER TRAIN AND END POST WEB
WEDGE SEAL
WEB ℞ 28 X 1/2 (TYP)
7/8" SKIN ℞
36'-7 1/2" SKIN ℞
FLANGE 18 X 1 1/2
FLANGE 20 X 1 1/2
FLANGE 16 X 1 1/2
FLANGE 12 X 1 1/2
FLANGE 12 X 1 1/8
FLANGE 4 X 1 1/8
FLANGE 12 X 1 1/8
FLANGE 16 X 1 1/2
FLANGE 6 X 1/2
BAR 6X1
TYP FOR 12" FLANGES
(TYP @ SPLICE)
2 SPACES @

PLATE 2

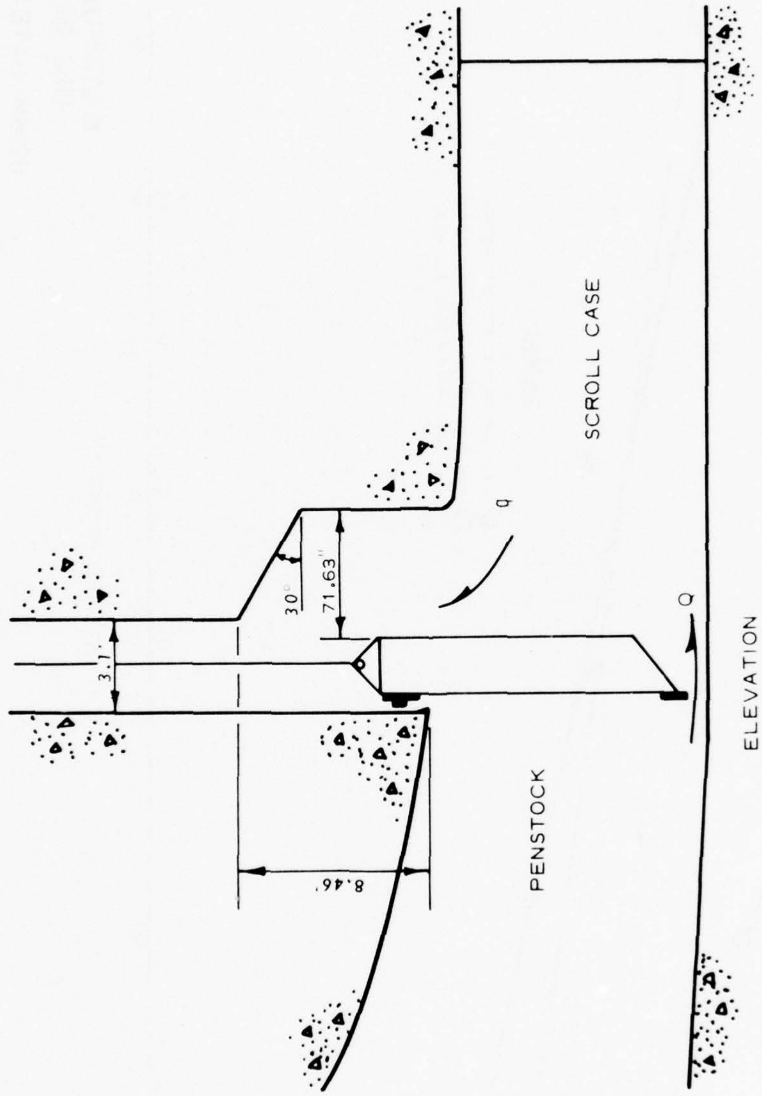


STOCKTON DAM

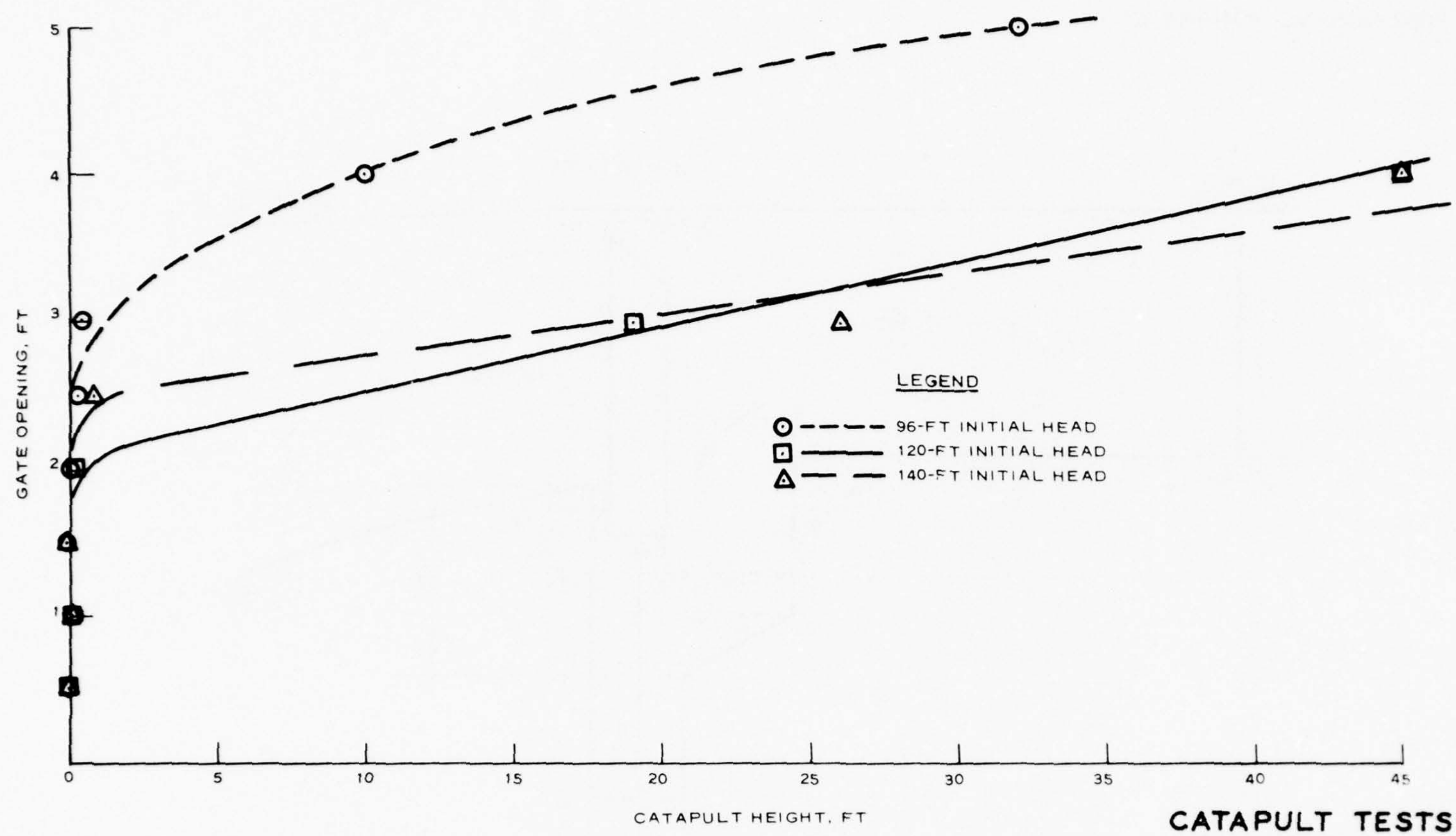
BACK-OF-GATE ORIFICE DESIGN



12-IN. BACK-OF-GATE ORIFICE DESIGN



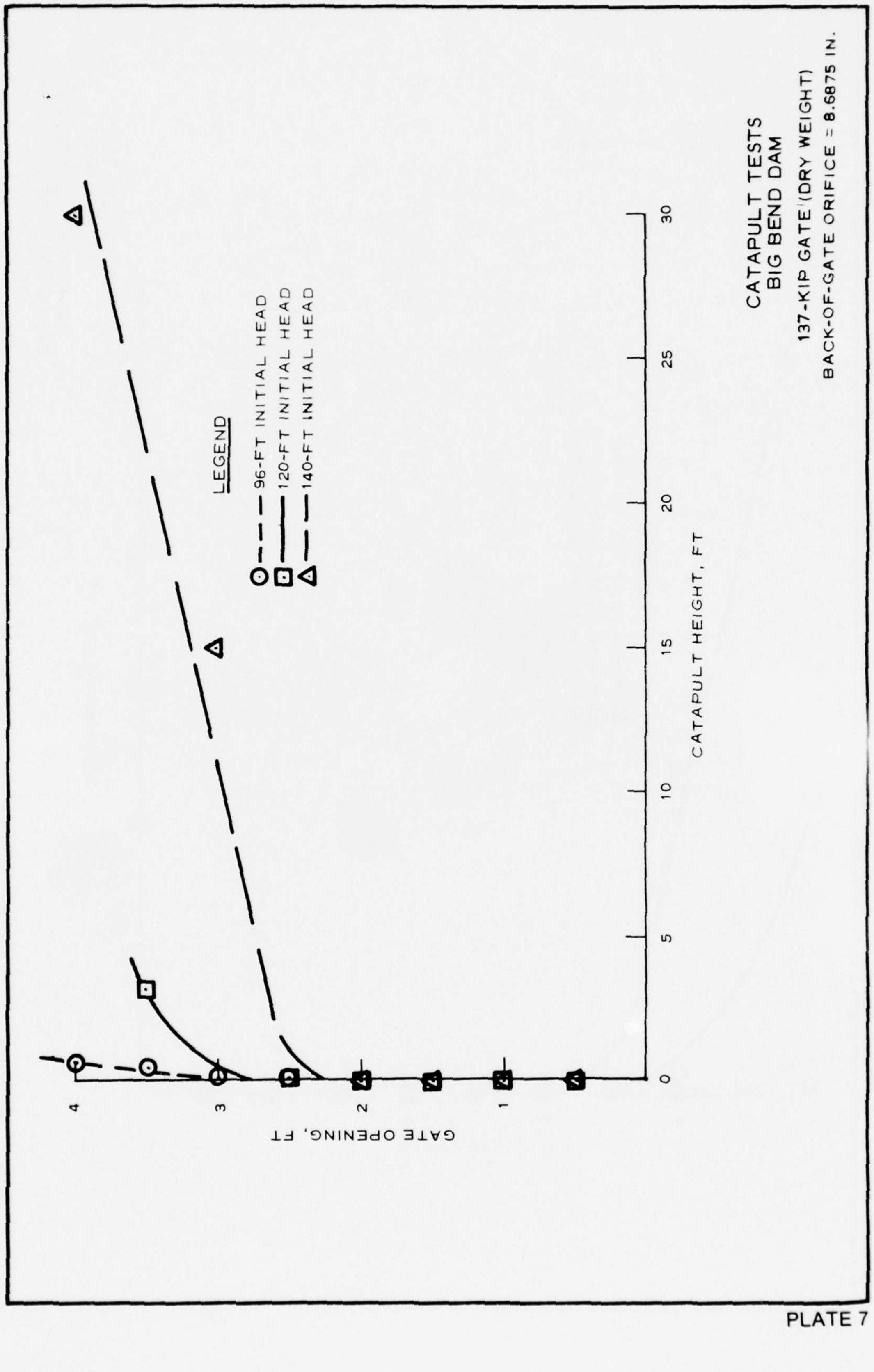
CLARENCE CANNON DAM
BACK-OF-GATE ORIFICE DESIGN



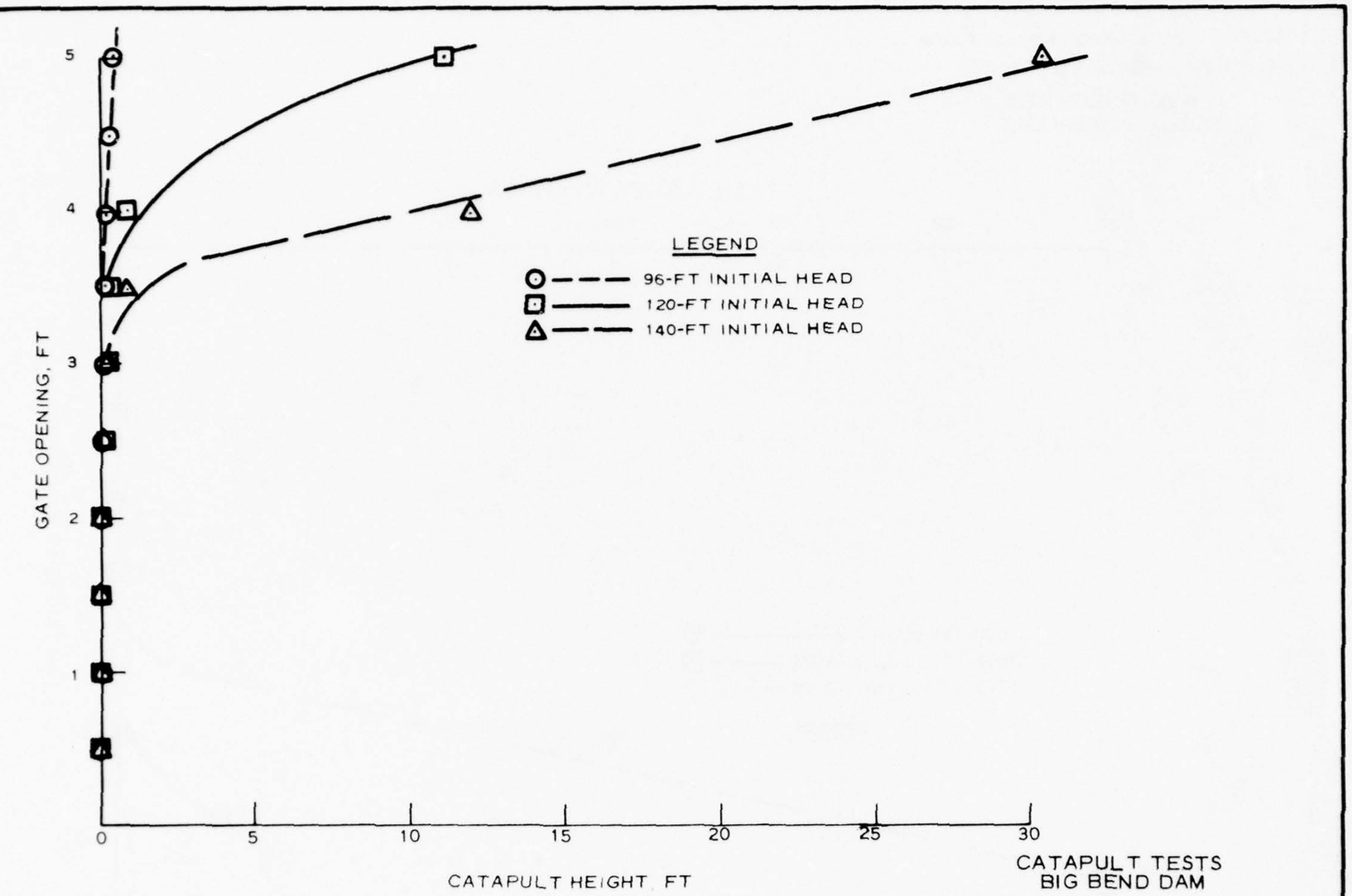
CATAPULT TESTS
BIG BEND DAM

110-KIP GATE (DRY WEIGHT)

BACK-OF-GATE ORIFICE = 8.6875 IN.



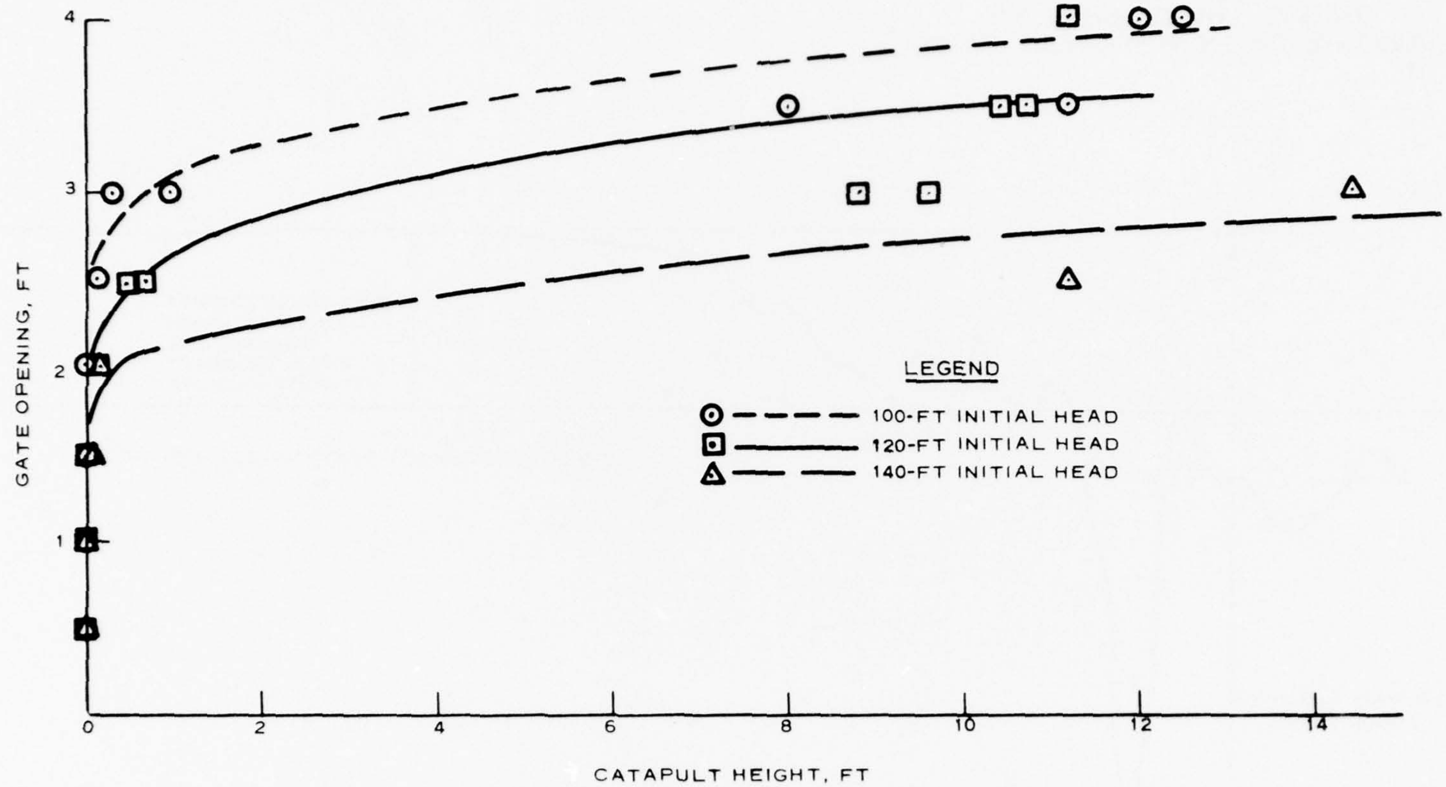
CATAPULT TESTS
BIG BEND DAM
137-KIP GATE (DRY WEIGHT)
BACK-OF-GATE ORIFICE = 8.6875 IN.



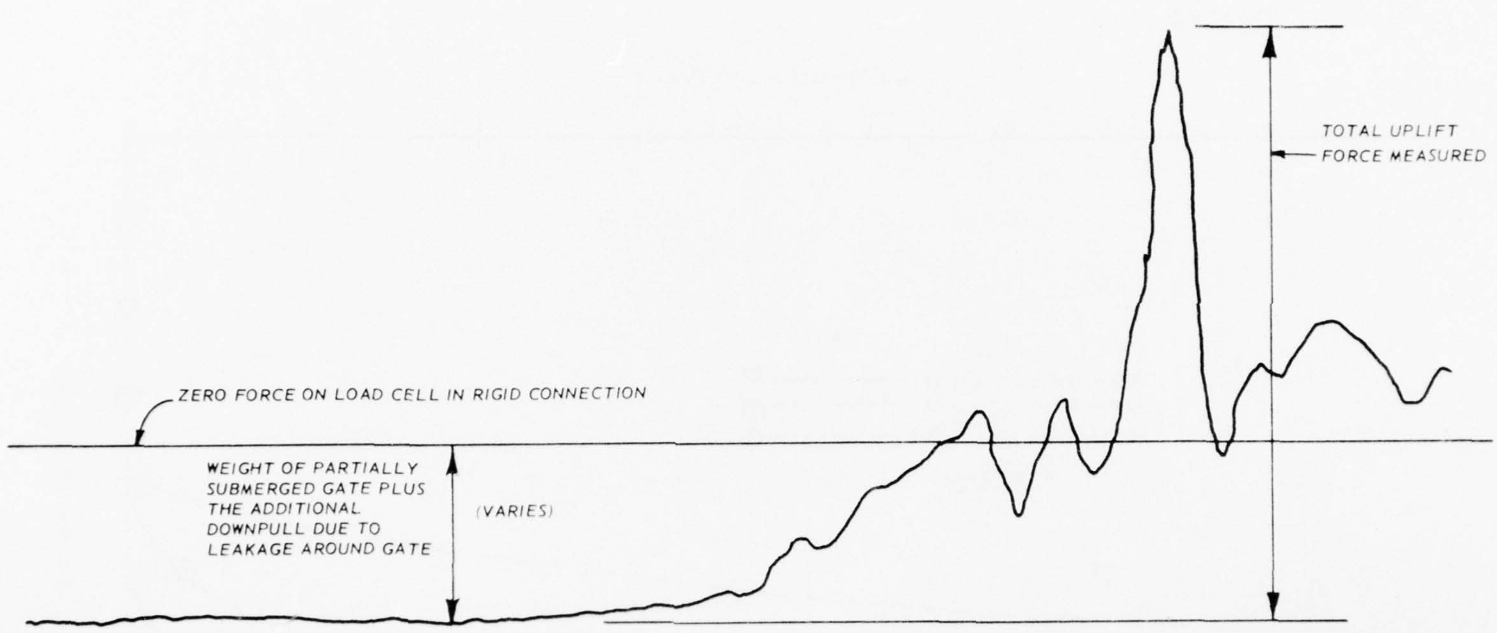
CATAPULT TESTS
BIG BEND DAM

150-KIP GATE (DRY WEIGHT)
BACK-OF-GATE ORIFICE = 8.6875 IN.

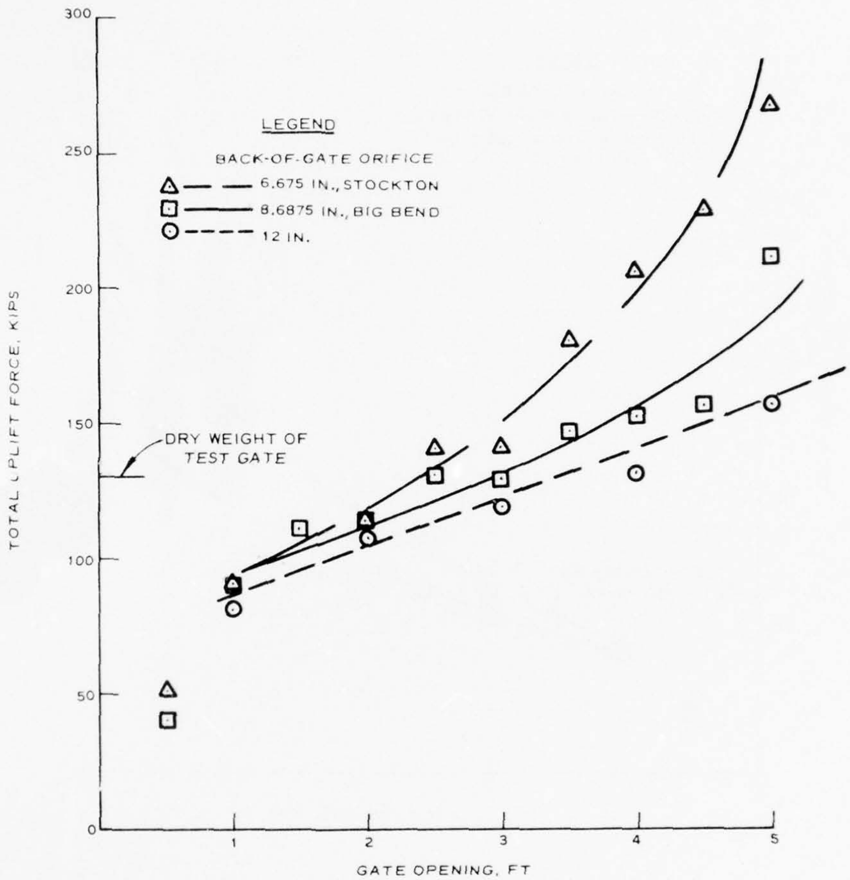
PLATE 8



CATAPULT TESTS
STOCKTON DAM
131-KIP GATE (DRY WEIGHT)
BACK-OF-GATE ORIFICE = 6.625 IN.

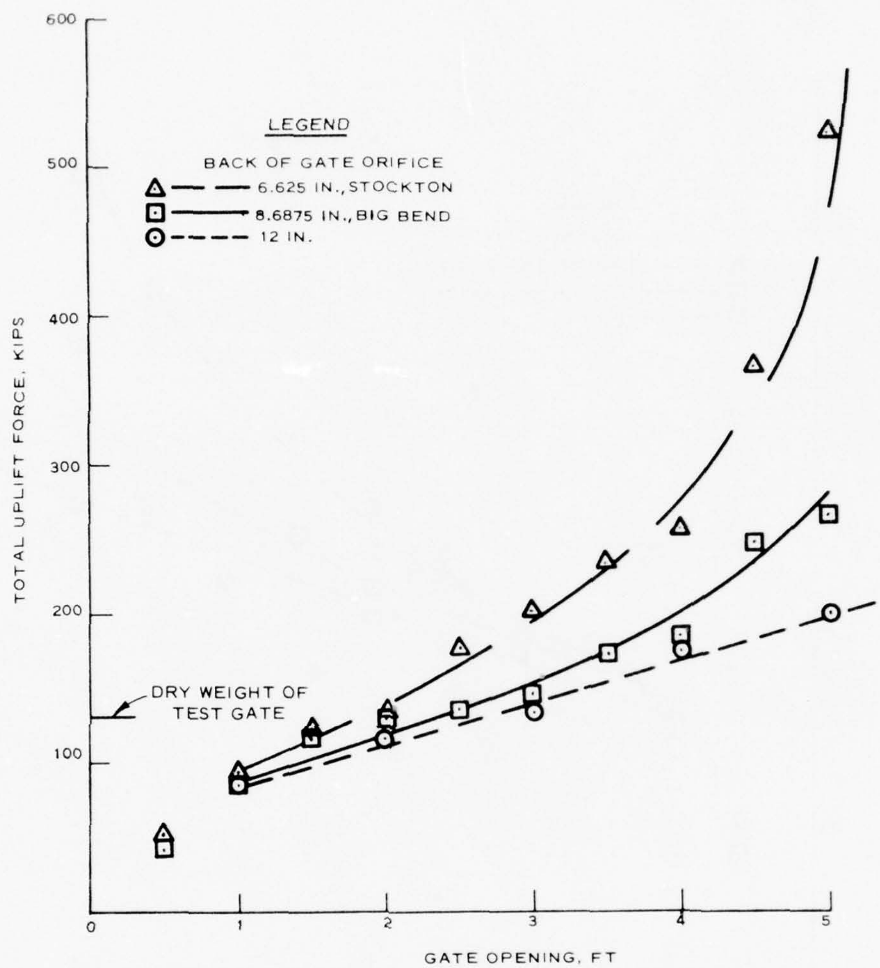


FORCE MEASUREMENT AS RECORDED ON STRIP CHART DURING MODEL TESTS



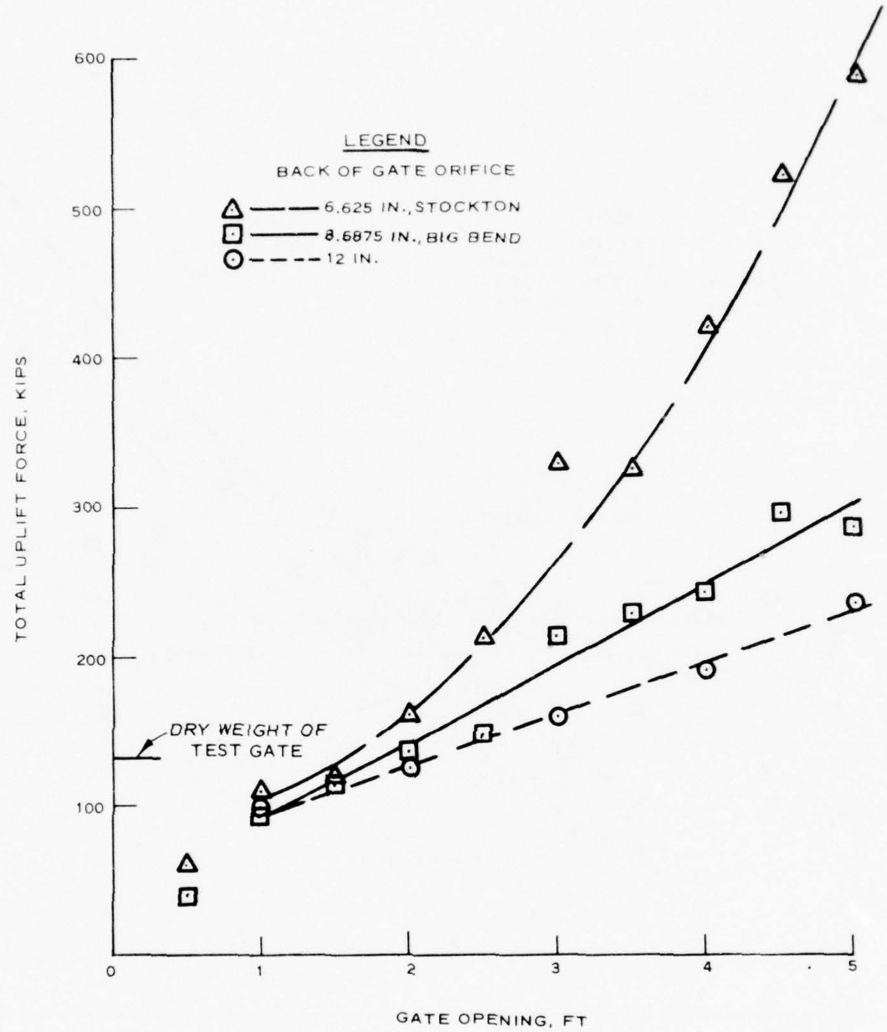
TOTAL UPLIFT FORCE
80-FT INITIAL HEAD

RIGID CONNECTION
LEFT BAY



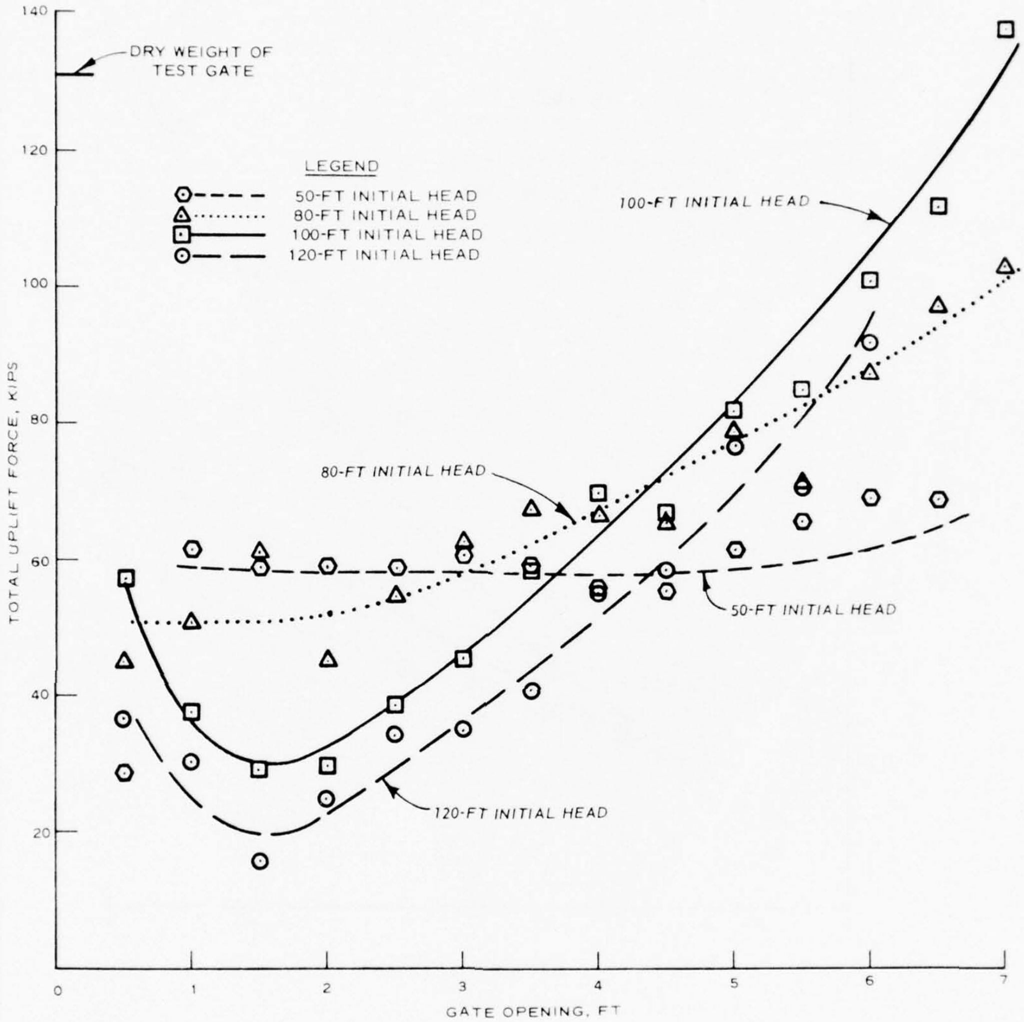
TOTAL UPLIFT FORCE
100-FT INITIAL HEAD

RIGID CONNECTION
LEFT BAY



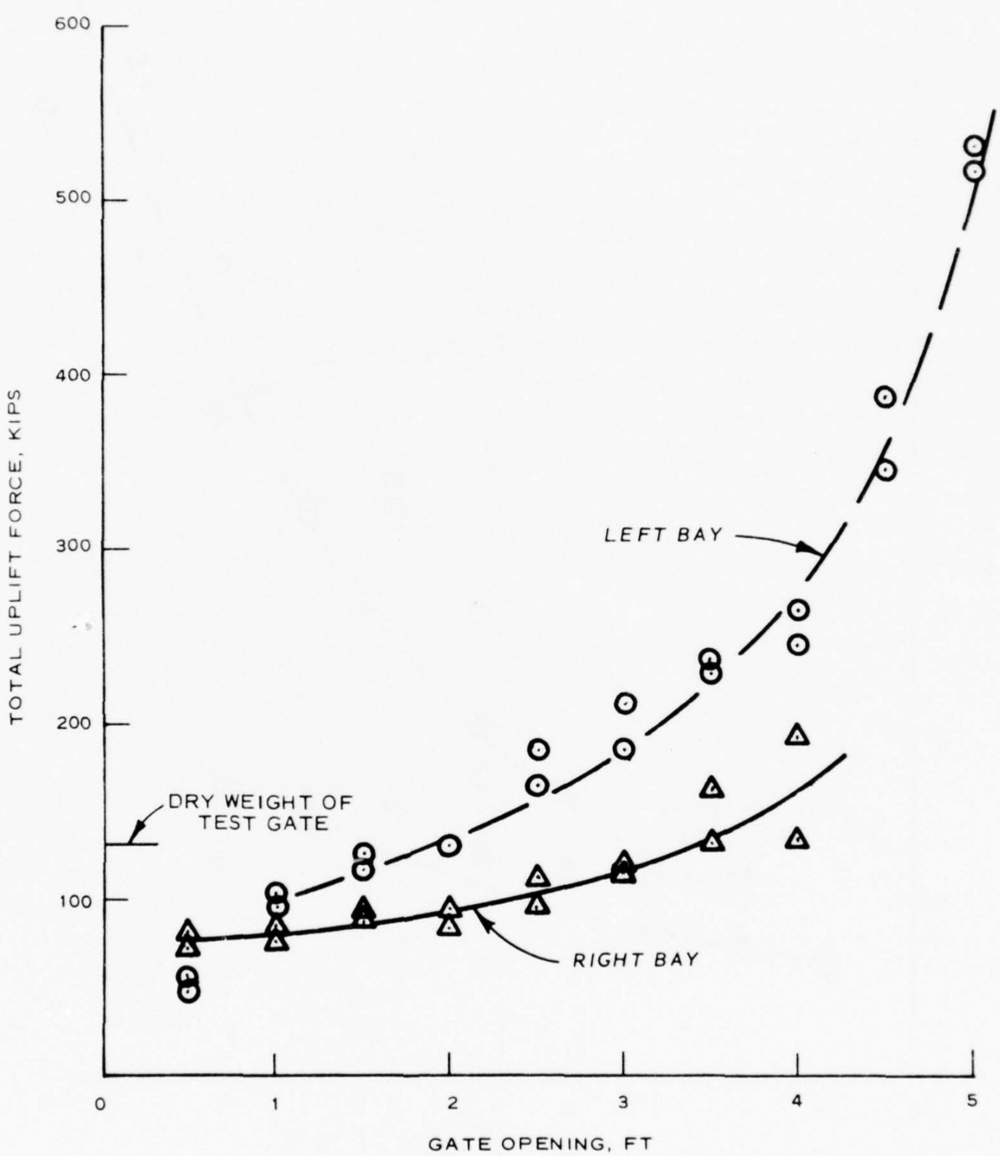
TOTAL UPLIFT FORCE
120-FT INITIAL HEAD

RIGID CONNECTION
LEFT BAY

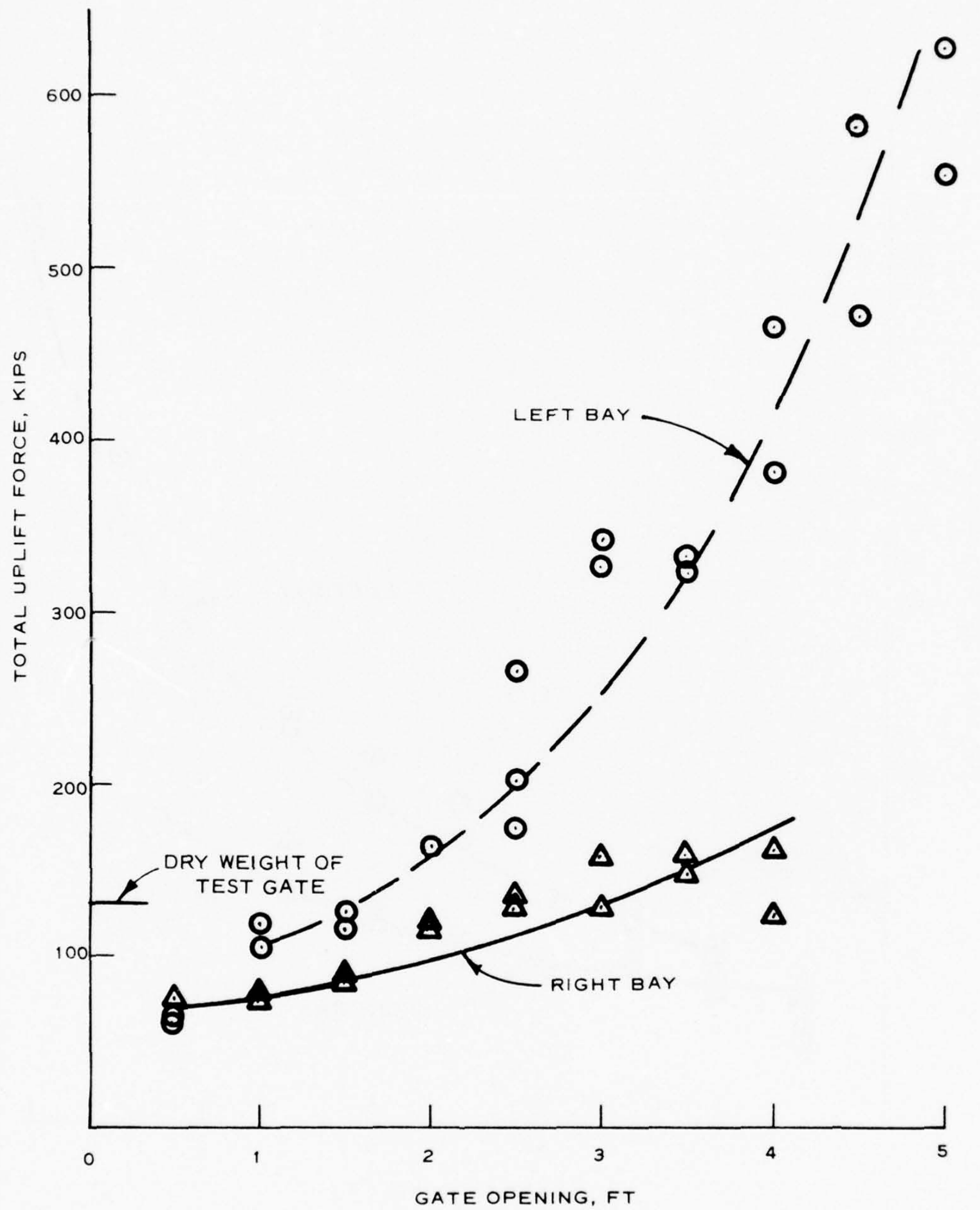


TOTAL UPLIFT FORCE
CLARENCE CANNON DAM

BACK-OF-GATE ORIFICE=71.63 IN.
RIGID CONNECTION
LEFT BAY

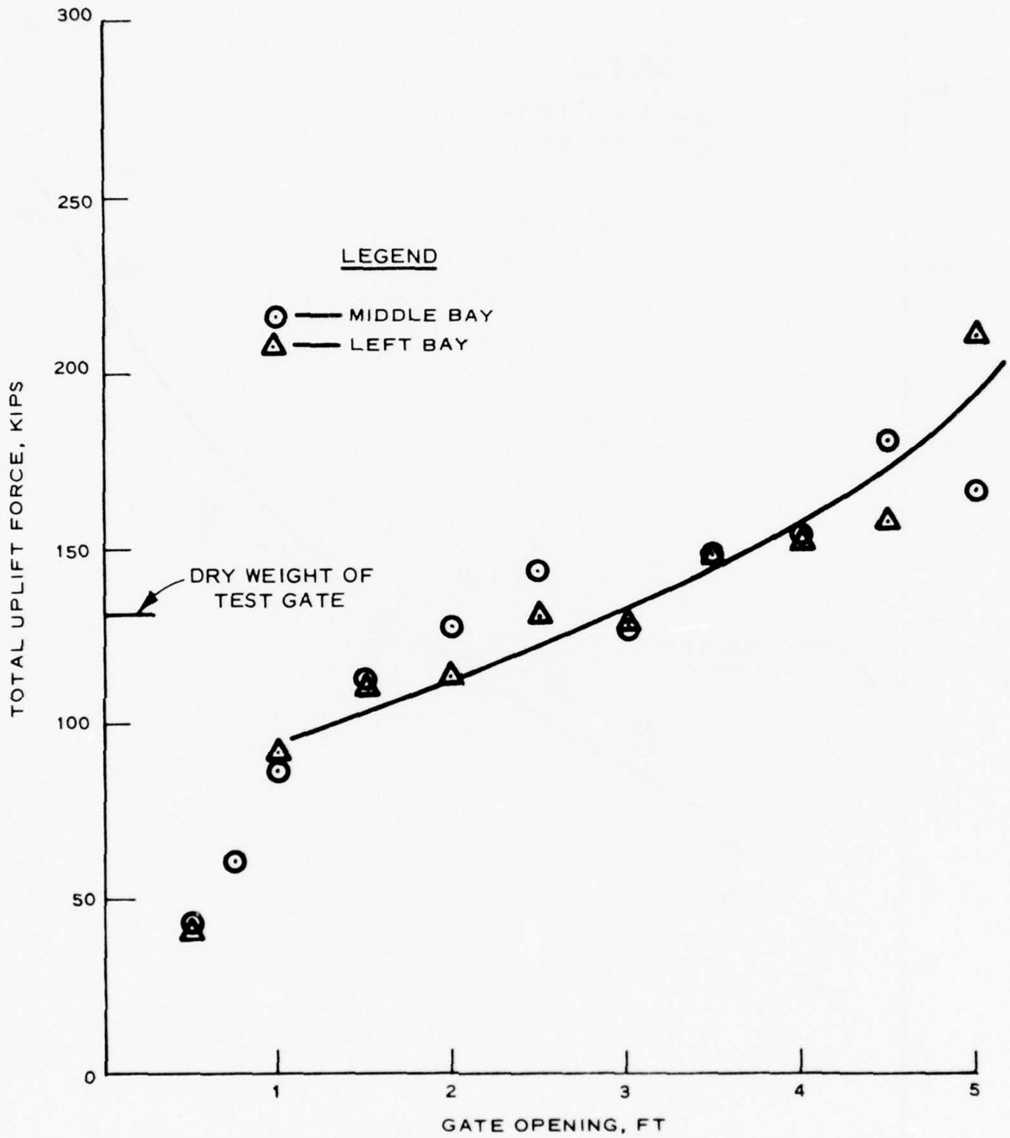


TOTAL UPLIFT FORCE
STOCKTON DAM
100-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 6.625 IN.
RIGID CONNECTION
LEFT AND RIGHT BAYS



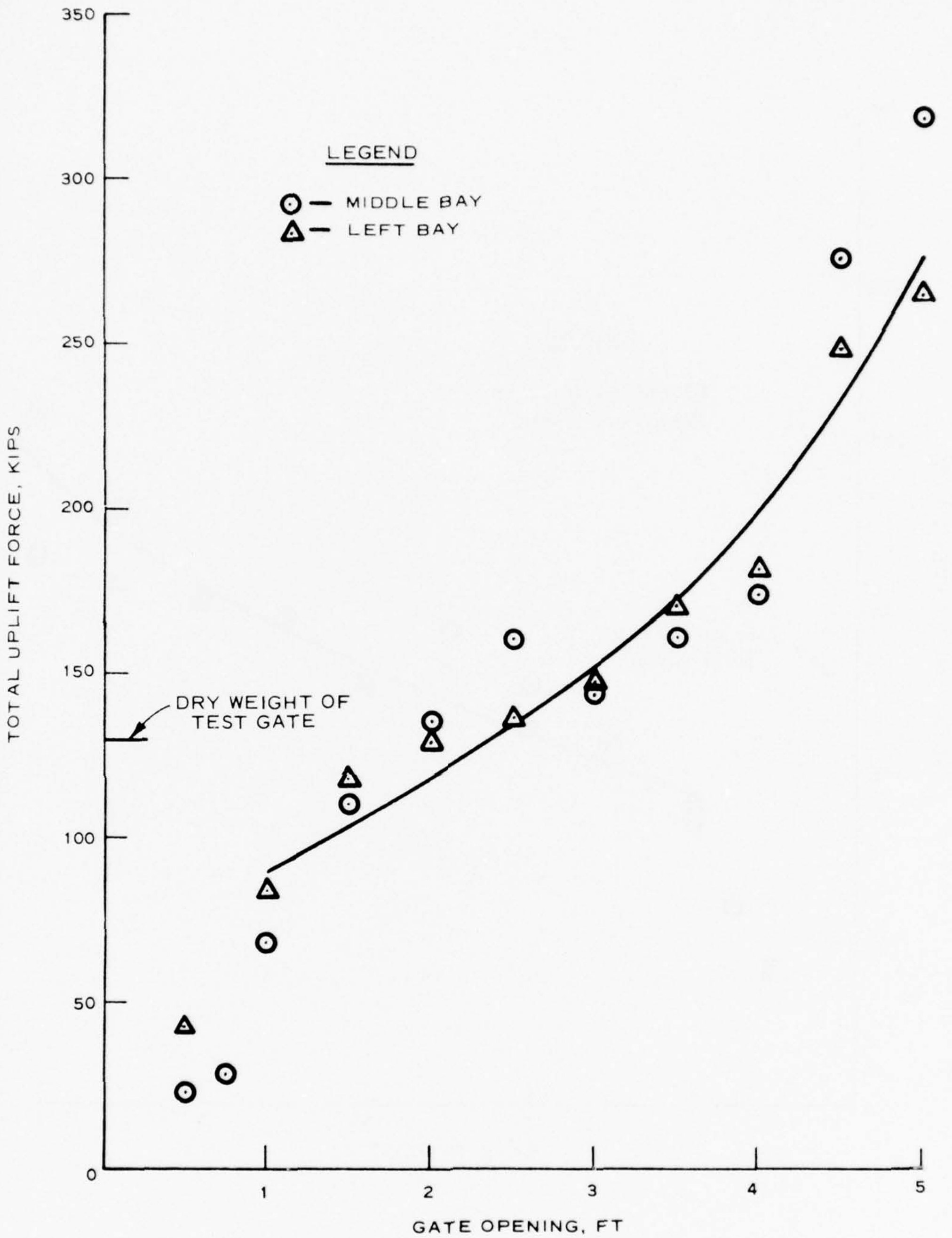
TOTAL UPLIFT FORCE
STOCKTON DAM

120-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 6.625 IN.
RIGID CONNECTION
LEFT AND RIGHT BAYS



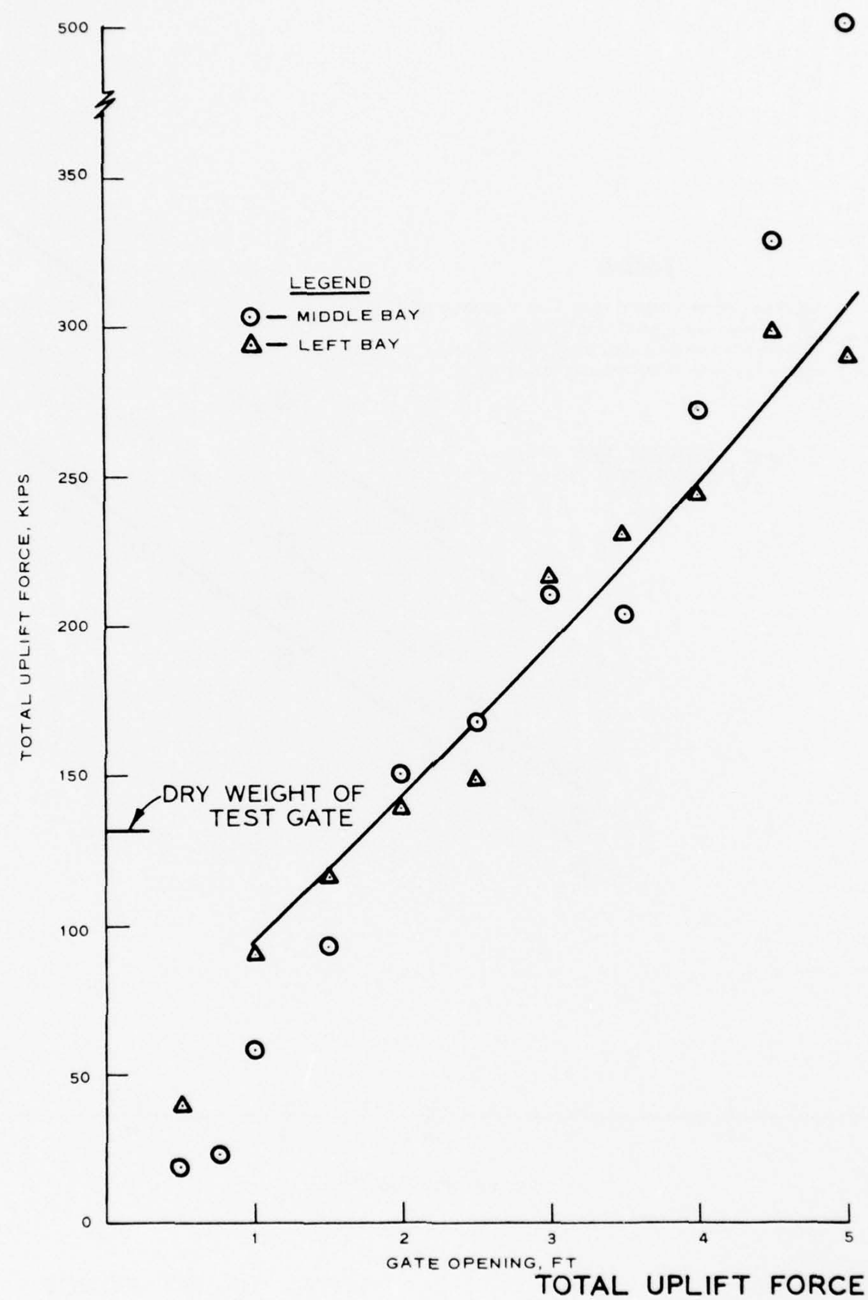
TOTAL UPLIFT FORCE
BIG BEND DAM

80-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
MIDDLE AND LEFT BAYS



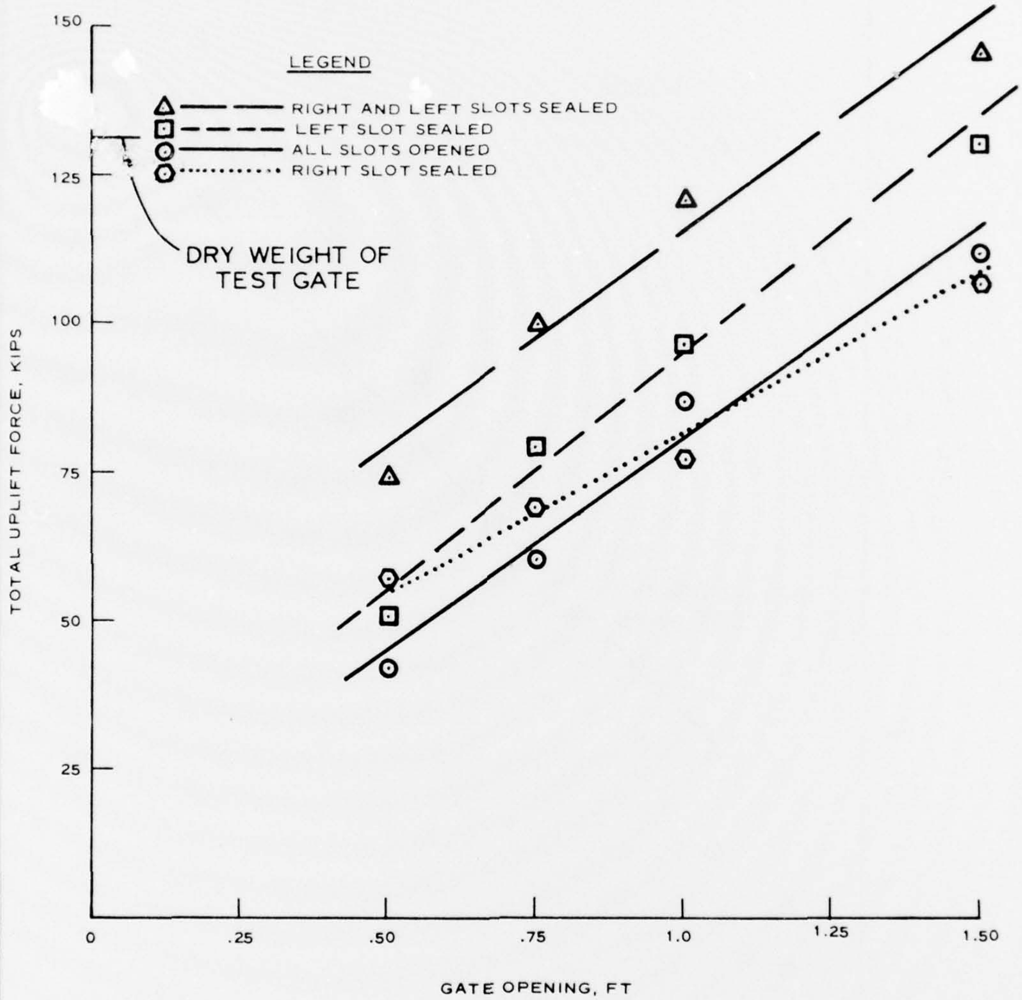
TOTAL UPLIFT FORCE
BIG BEND DAM

100-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
MIDDLE AND LEFT BAYS

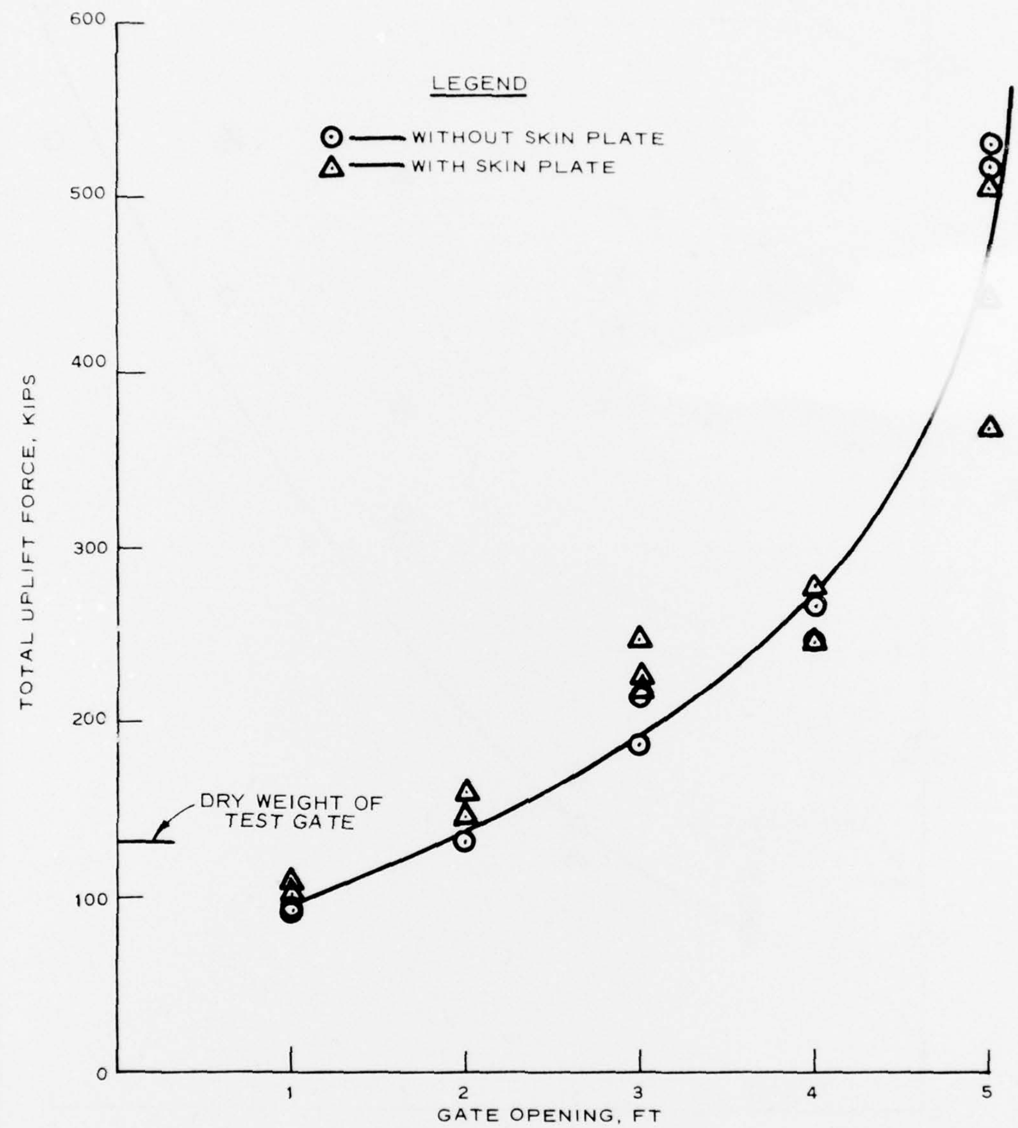


TOTAL UPLIFT FORCE
BIG BEND DAM
120-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
MIDDLE AND LEFT BAYS

PLATE 19

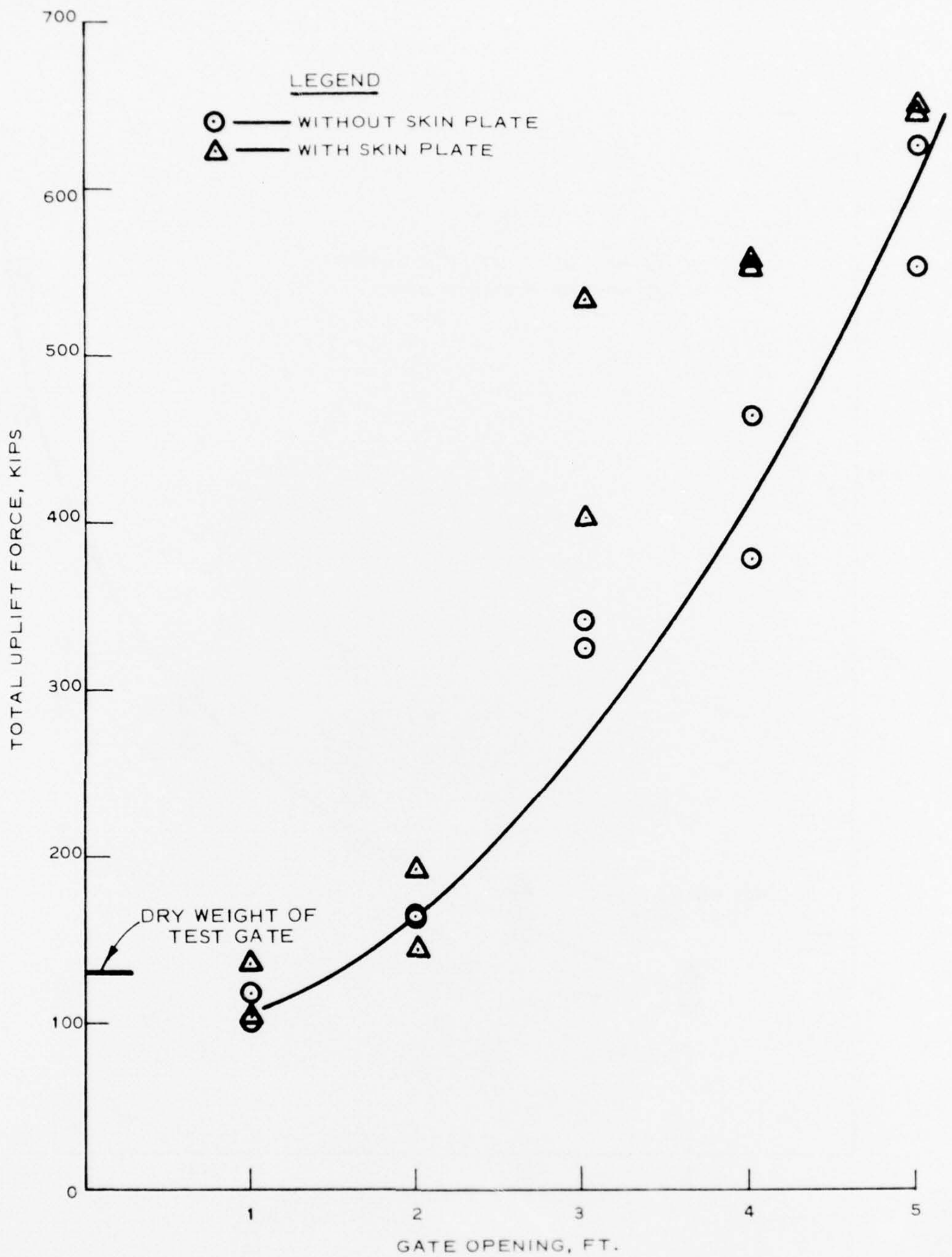


TOTAL UPLIFT FORCE
BIG BEND DAM
80-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
MIDDLE BAY



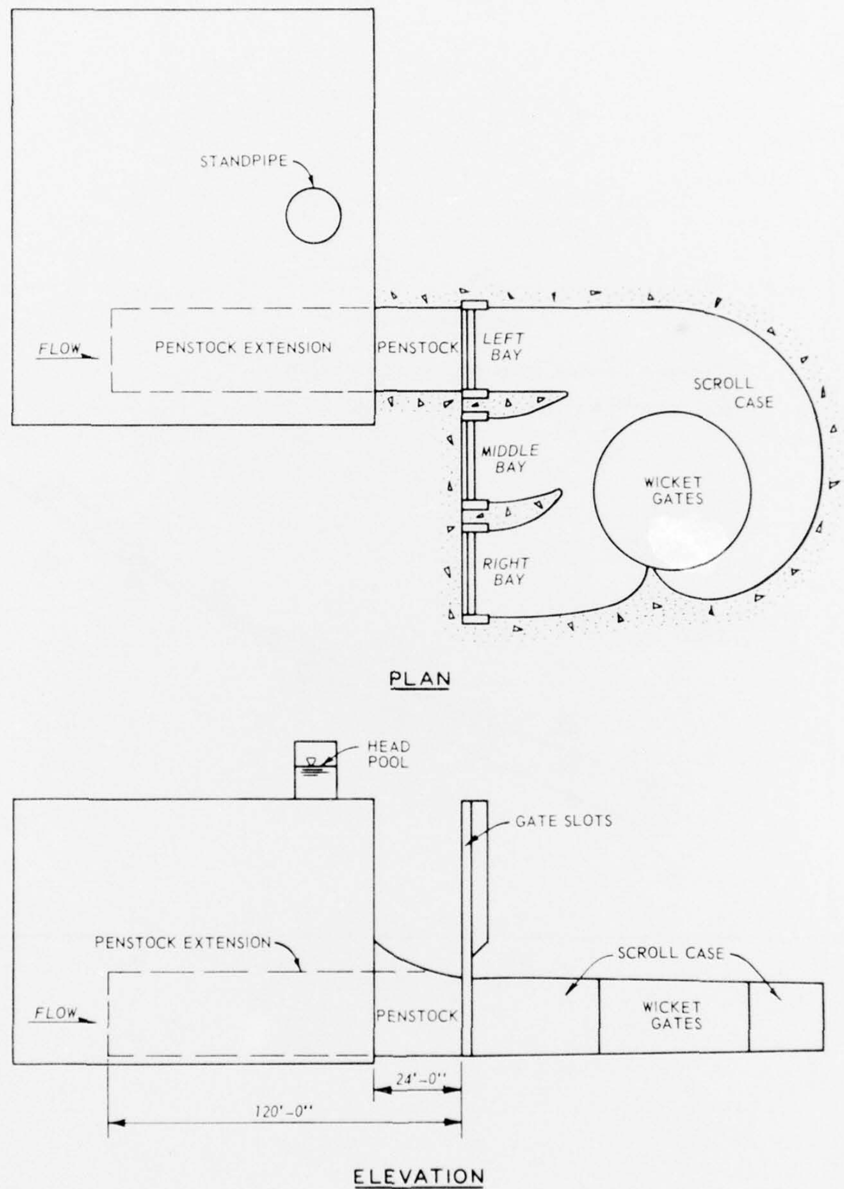
TOTAL UPLIFT FORCE
STOCKTON DAM

100-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 6.625 IN.
RIGID CONNECTION
LEFT BAY

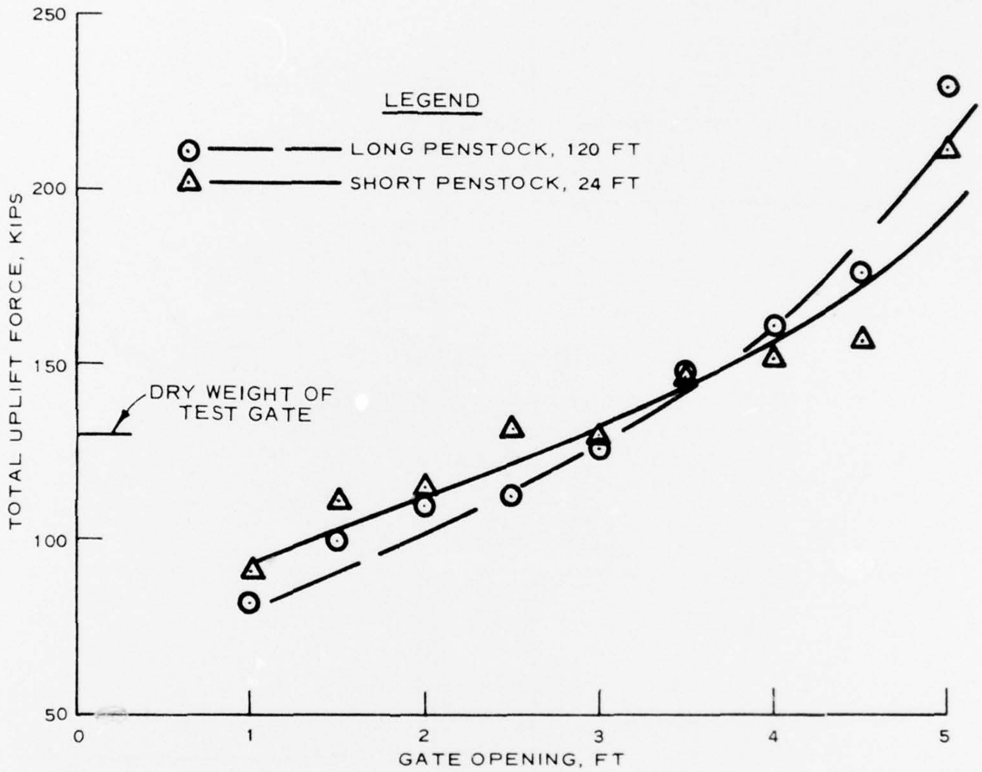


TOTAL UPLIFT FORCE
STOCKTON DAM

120-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 6.625 IN.
RIGID CONNECTION
LEFT BAY

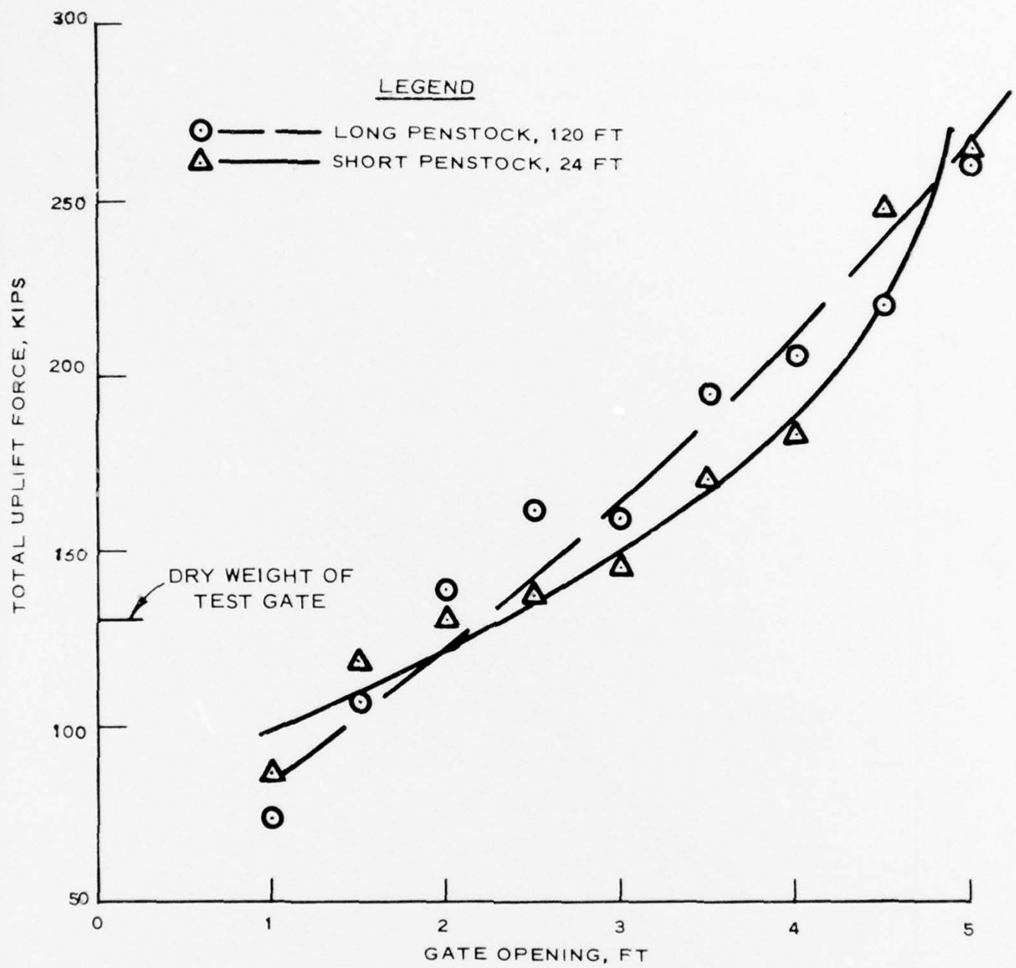


LOCATION OF
PENSTOCK EXTENSION



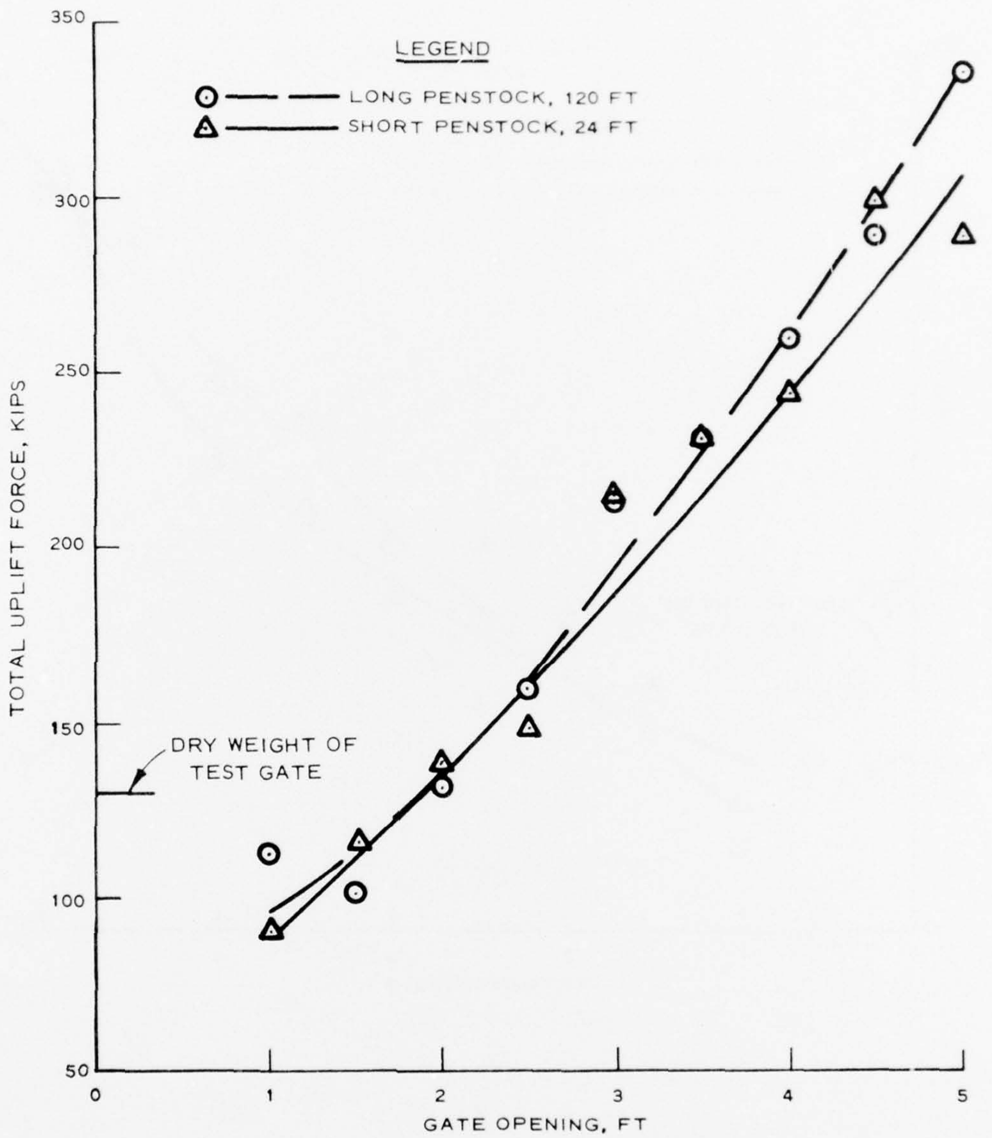
TOTAL UPLIFT FORCE
BIG BEND DAM

80-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
LEFT BAY



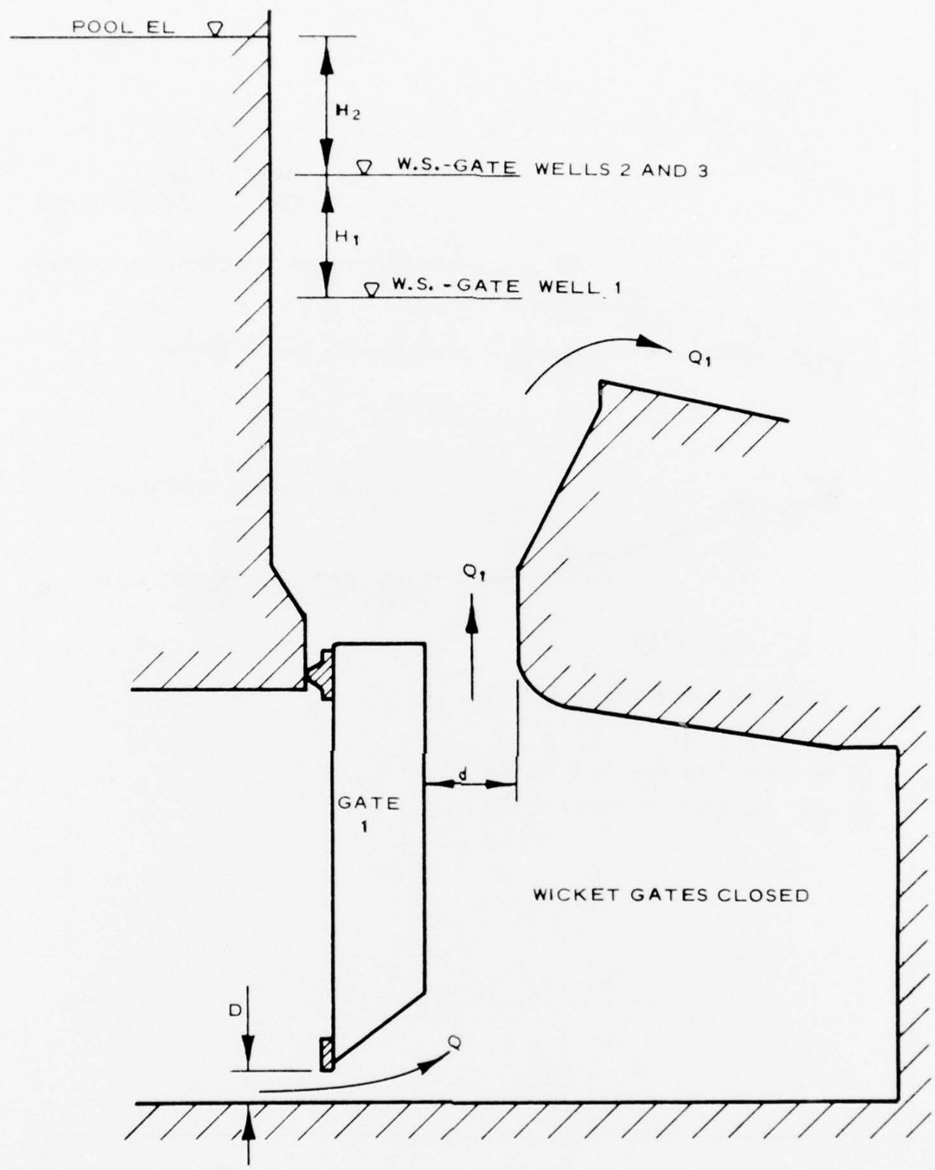
TOTAL UPLIFT FORCE
BIG BEND DAM

100-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
LEFT BAY

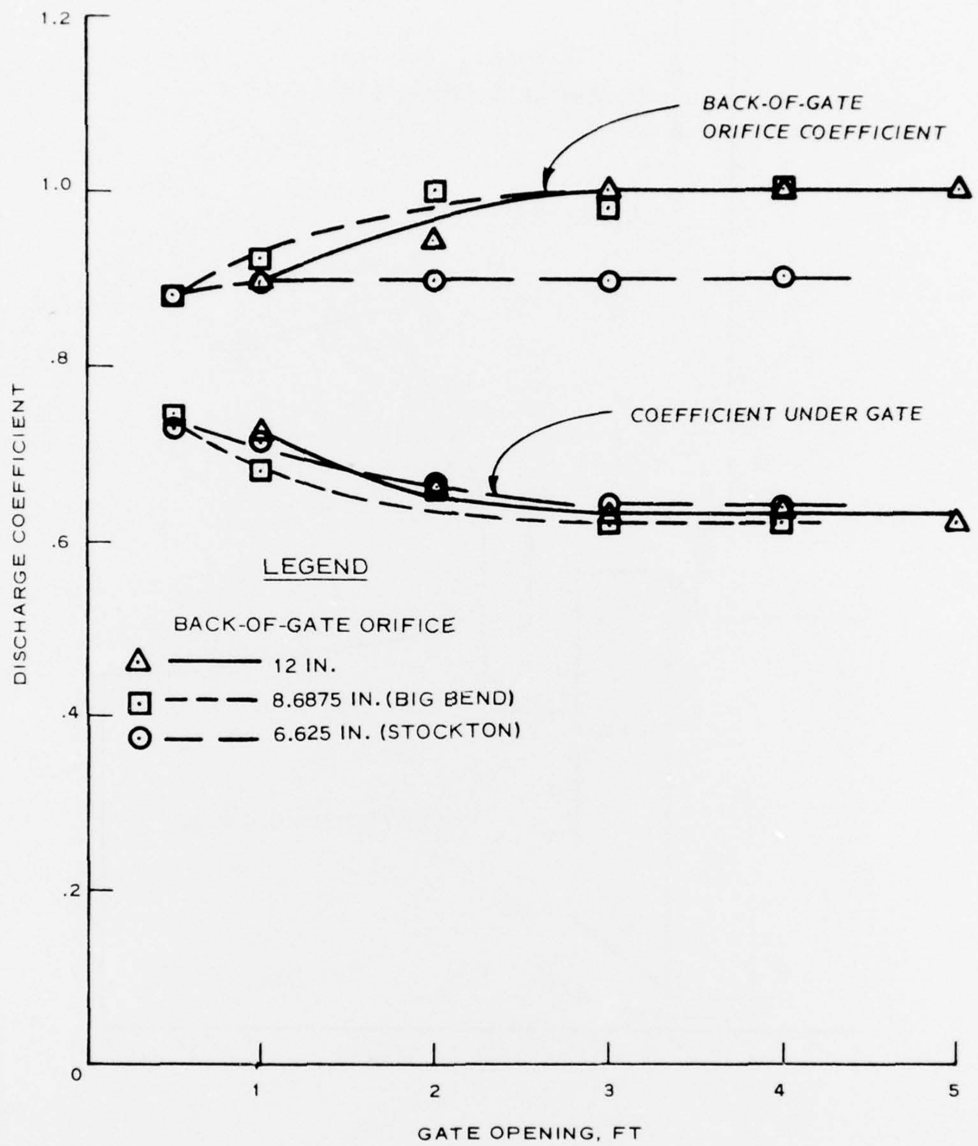


TOTAL UPLIFT FORCE
BIG BEND DAM

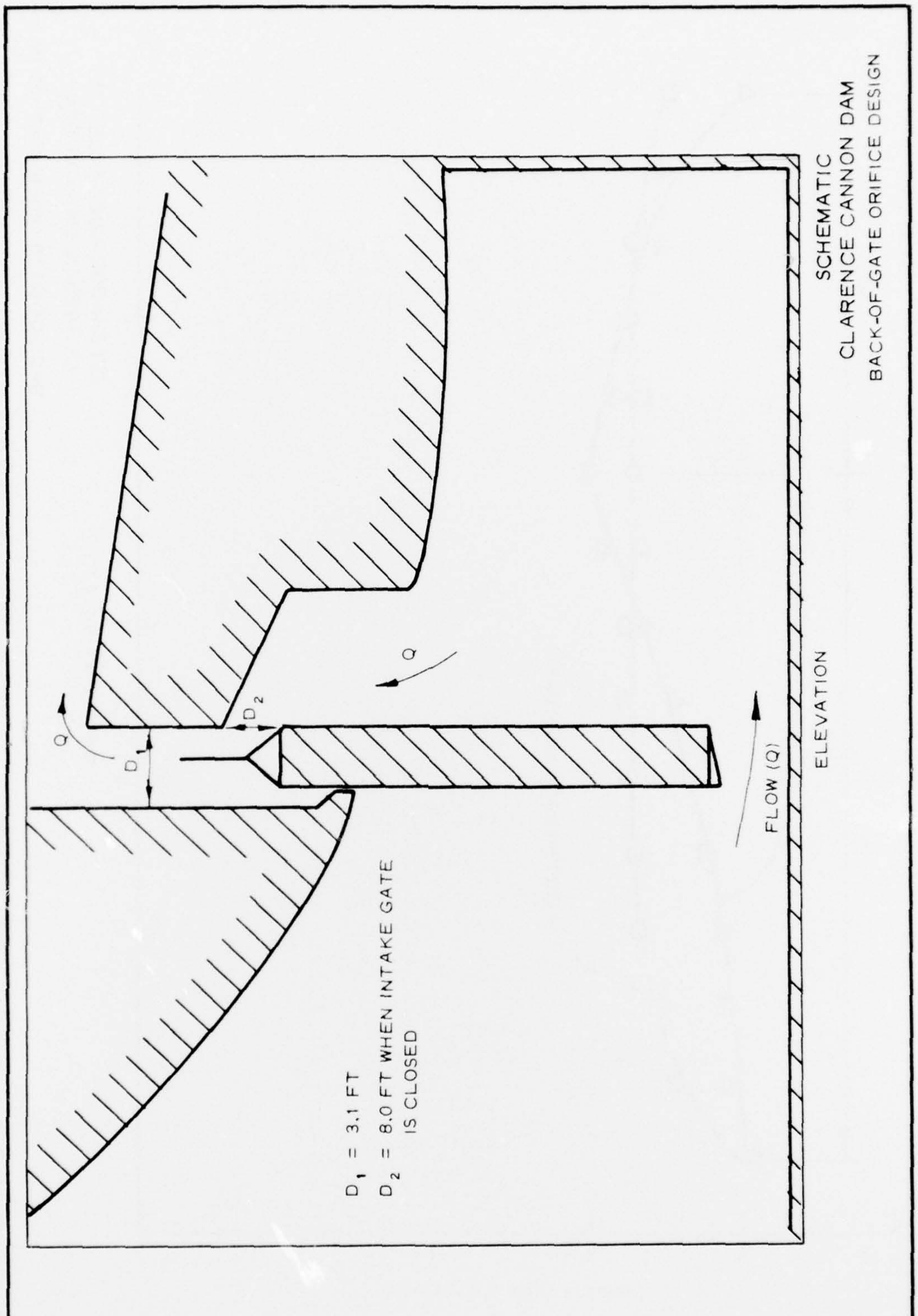
120-FT INITIAL HEAD
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
LEFT BAY



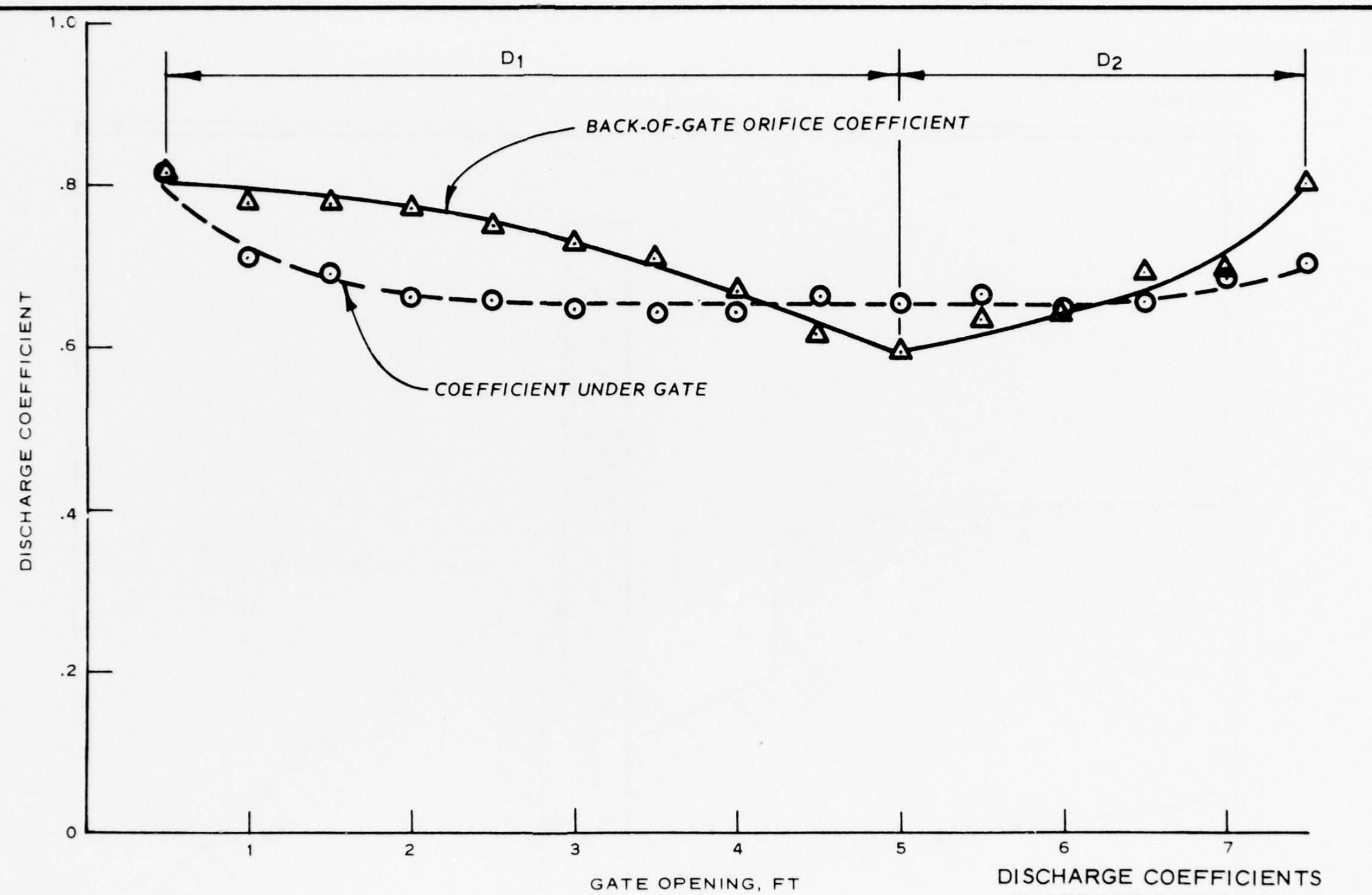
TEST CONDITIONS TO DETERMINE
DISCHARGE COEFFICIENTS



DISCHARGE COEFFICIENTS

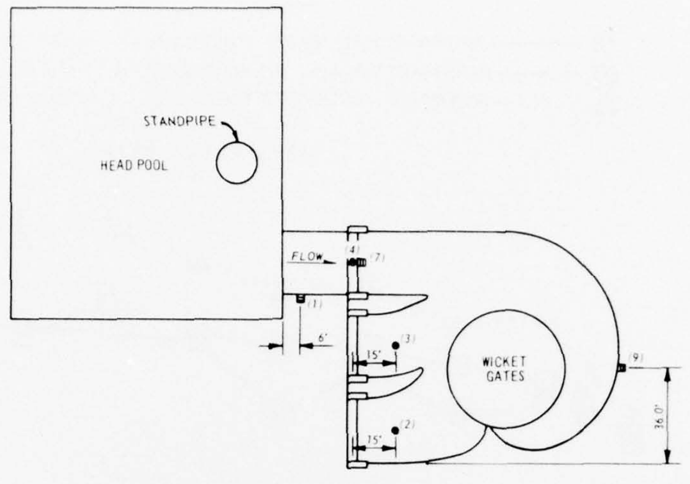


SCHEMATIC
CLARENCE CANNON DAM
BACK-OF-GATE ORIFICE DESIGN

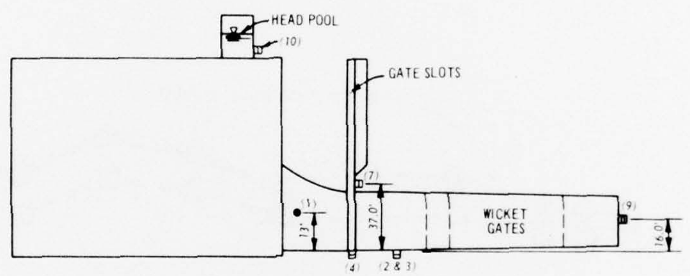


DISCHARGE COEFFICIENTS
CLARENCE CANNON DAM

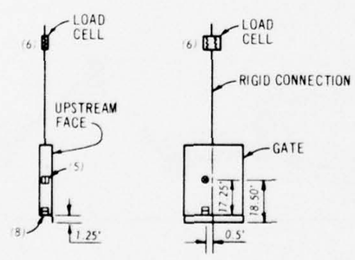
BACK-OF-GATE ORIFICE = 71.63 IN.



PLAN



ELEVATION



GATE

1. PENSTOCK
2. SLOT 3 (CENTER OF BAY 3)
3. SLOT 2 (CENTER OF BAY 2)
4. BOTTOM OF SLOT 1 (CENTER OF SLOT 1)
5. MIDDLE OF GATE (OFF LONGITUDINAL CENTERLINE 0.5')
6. LOAD CELL ON RIGID CONNECTION
7. BACK-OF-GATE ORIFICE
8. BOTTOM OF GATE (OFF LONGITUDINAL CENTERLINE 0.5')
9. SCROLL CASE
10. STANDPIPE (HEAD POOL)

LOCATION OF PRESSURE CELLS

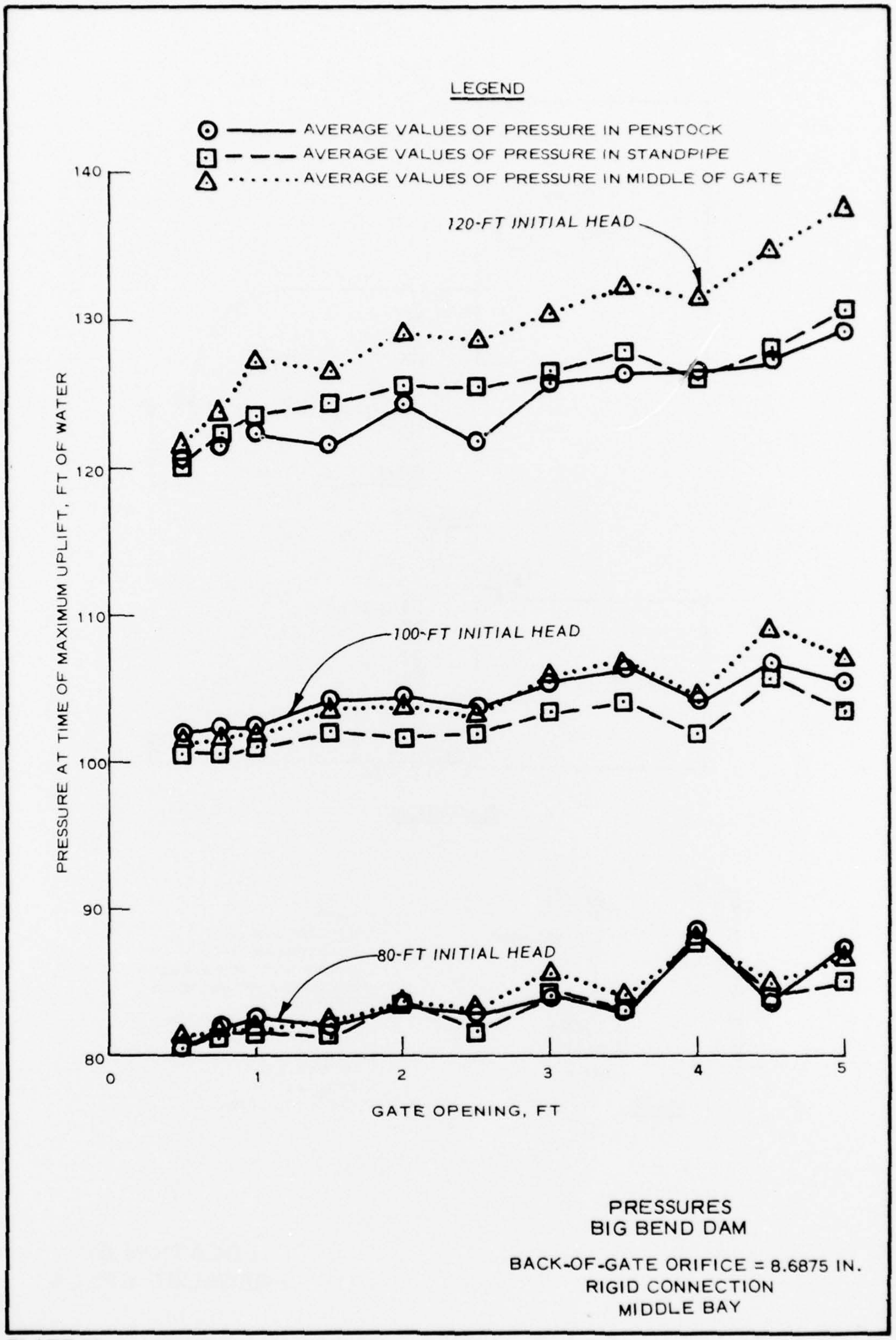

LEGEND
AVERAGE VALUES OF PRESSURE IN PENSTOCK
AVERAGE VALUES OF PRESSURE IN STANDPIPE
AVERAGE VALUES OF PRESSURE IN MIDDLE OF GATE
120-FT INITIAL HEAD
100-FT INITIAL HEAD
80-FT INITIAL HEAD
PRESSURE AT TIME OF MAXIMUM UPLIFT, FT OF WATER
GATE OPENING, FT
140
130
120
110
100
90
80
0
1
2
3
4
5
PRESSURES
BIG BEND DAM
BACK-OF-GATE ORIFICE = 8.6875 IN.
RIGID CONNECTION
MIDDLE BAY

PLATE 32

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

George, John F

Powerhouse intake gate catapult study, Big Bend Dam, South Dakota, and Stockton, Harry S. Truman, and Clarence Cannon Dams, Missouri; hydraulic model investigation, by John F. George [and] Glenn A. Pickering. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.

1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report H-77-8)

Prepared for U. S. Army Engineer District, Omaha, Omaha, Nebraska; U. S. Army Engineer District, Kansas City, Kansas City, Missouri; [and] U. S. Army Engineer District, St. Louis, St. Louis, Missouri.

1. Big Bend Dam. 2. Clarence Cannon Dam. 3. Electric power plants. 4. Gates (Hydraulic structures). 5. Harry S. Truman Dam. 6. Hydraulic structures. 7. Intake structures. 8. Stockton Dam. I. Pickering, Glenn A., joint author. II. U. S. Army Engineer District, Omaha. III. U. S. Army Engineer District, Kansas City. IV. U. S. Army Engineer District, St. Louis. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report H-77-8)

TA7.W34 no.H-77-8