Division of Engineering Laboratories
Hydraulic Laboratory Branch

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MODEL STUDIES OF CLEAR CREEK POWER CONDUIT SURGE TANK--TRINITY RIVER DIVISION CENTRAL VALLEY PROJECT

Hydraulic Laboratory Report Hyd-438

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
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Commissioner's Office, Denver
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Hydraulic Equipment and Structures Section
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Subject: Model Studies of Clear Creek Power Conduit Surge Tank--Trinity River Division--Central Valley Project

INTRODUCTION

In compliance with a memorandum request dated September 28, 1956, from the Chief, Canals Branch, model studies have been made as follows:

(a) A study to determine the location, size, and shape of a battery of ports such that a discharge of 3,200 cfs will pass from the standpipe through the ports and into the surge tank when the water surface in the standpipe is 40 feet higher than that in the tank and so shaped that adverse pressure conditions will not exist. These tests were made on a 1:21 scale model using air as the test fluid.

(b) A study to assure that acceptable flow conditions will exist when water spills over the top of the standpipe into the surge tank. These tests were made with the aid of a 1:18 scale hydraulic model.

The surge tank and storage basin will be required to damp and contain the flow which would result from the simultaneous load rejection from both turbines in the powerhouse. Normal discharge through the turbines is 3,200 cfs, and the 17-1/2-foot-diameter power penstock is approximately 56,000 feet long from the intake at the reservoir to the surge tank opening. The general arrangement of the surge tank is shown in Figure 1.

PORTS

The discharge coefficients and pressure conditions pertaining to the ports were studied in an air model (Figure 2A). The model was so constructed that rate of flow could be measured in the conduit both upstream and downstream from the surge tank opening and in the standpipe above the port manifold. Air could be forced out through the ports simulating a load rejection or drawn in through the ports simulating a sudden water demand by a turbine. Figure 2B shows the ports as tested.

During operation of the surge tank the flow conditions at the prototype will be continually changing. A second or two after a load rejection with the total flow of 3,200 cfs going into the standpipe, the water surface in the standpipe will be rising about 11 feet per second with perhaps 1,000 cfs passing through the ports. When the water surface reaches the top of the standpipe it will be rising about 2.2 feet per second and the flow through the ports will be about 2,760 cfs. The surge tank water surface at this time will be 37.2 feet below that in the standpipe. As the cycle continues, water will spill over the top of the standpipe in ever increasing quantities with correspondingly decreasing amounts passing through the ports due to the decrease in differential head across the ports until the total flow diminishes and gradually stops altogether.

The air model could not be operated under gradually changing conditions; instead a series of tests were made in which various flow conditions were established and discharges and pressures noted so that families of curves could be drawn to represent the instantaneous conditions prevailing under almost any conceivable flow distribution through the system.

The relationship between pressures throughout the system varied as the ratios of amounts of flow changed. Flow from the reservoir could be distributed in any combination of: (1) on down the conduit, (2) up the standpipe, or (3) out through the ports into the surge tank. These three conditions would be similar but reversed for flow in the opposite direction. Two charts (Figures 3 and 5) have been drawn to enable determination of the pressure relationships between head in the conduit, head in the standpipe, and head in the surge tank for known or assigned flow ratios.

The discharge coefficient C_p for the port manifold was computed from the equation:

$$Q_p = C_p A_p \sqrt{2g}\sqrt{H_s}$$

where

Q_p = the discharge passing through the ports
A_p = total area of ports as shown in Figure 6
g = acceleration of gravity
H_s = head differential between the standpipe and the surge tank, feet of water

The coefficient changed as the discharge rates through the system changed. The results are plotted in Figures 4 and 6.

One of the design requirements of the ports was that a differential head of 40 feet between the standpipe and surge tank should give a flow of 3,200 cfs out through the ports. Using a discharge coefficient of 0.75 (Figure 4) the total port area was determined to be 83.90 square feet. The recommended port dimensions are shown on Figure 7. The tests disclosed that adverse pressure conditions did not exist on or near the port surfaces.

TOP OF THE STANDPIPE

(These studies were made assuming a combined discharge of 3,200 cfs out through the ports and up the standpipe.)

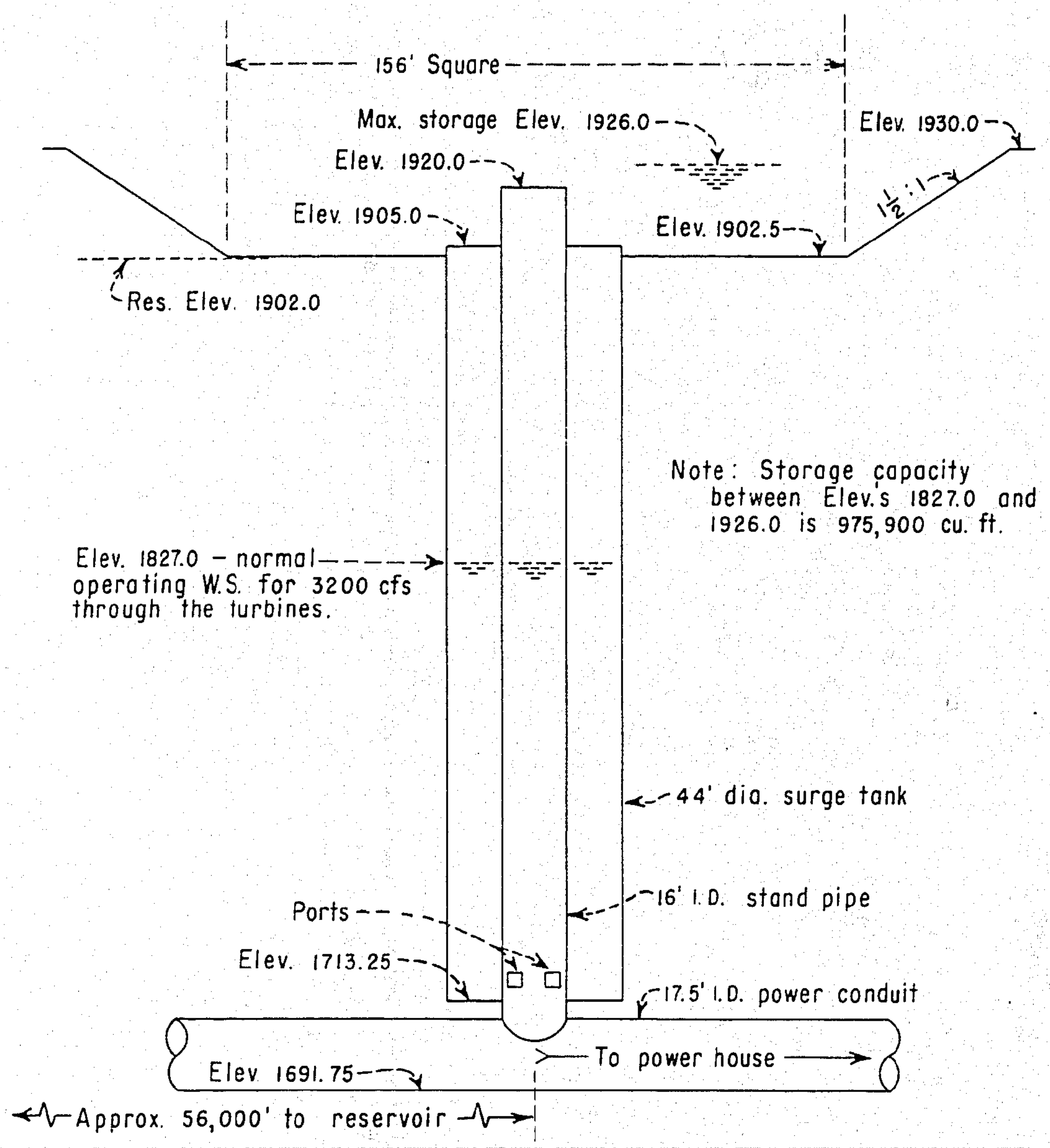
When flow first tops the standpipe, the water surface in the standpipe will be about 37.2 feet below the top of the pipe with 2,760 cfs passing through the ports. As the cycle proceeds the differential between the water surface in the standpipe and that in the tank will gradually decrease with a corresponding increase in the flow over the top of the standpipe. With a 6-inch-radius crest (Figure 8A) the flow over the crest would cling to the outside surface of the pipe (Figure 8B) until the discharge reached about 900 cfs where it would spring free and fall in a solid nappe to the water surface in the surge tank. As the free unbroken nappe falls to the surge tank water surface, pressure under the nappe will vary depending on the movement and elevation of the tank water surface and might be either positive or negative. Figure 9A shows the flow conditions for 815 cfs with a negative pressure under the nappe and the stream following a path marked by the point gage. Figure 9B shows the same discharge but with the nappe broken to allow complete aeration, the stream here follows a path somewhat different than before as shown by the point gage which has not been moved.

The flow conditions over the top of the standpipe with the 6-inch-radius crest were unsteady and unpredictable. The pressures on the walls of the pipe and the path of the nappe were subject to rapid change. These conditions were unsatisfactory, therefore, the shape of the crest was changed to achieve steady predictable flow.

The lip was extended outward 6 inches beyond the outside wall of the pipe, sloped downward 30° from the horizontal and made tangent to the crest. The lower part of the lip sloped down and back 60° from the horizontal (Figure 12). Four triangular piers at the crest quarter points were installed to split the flow and allow aeration under the nappe (Figure 10A).

Flow with this design was satisfactory for discharges up to 400 cfs and above 900 cfs. Between 400 and 900 cfs the pressure on the sloping portion of the lip in contact with the flow became negative and allowed the stream to cling to the surface (Figure 11). To aerate this surface four 3-inch-wide slots were made in the lip, one 45° from each pier. Flow with this design was good for all discharges (Figure 10B).

The recommended dimensions of the top of the standpipe are shown in Figure 12. Figure 11 shows the path of the upper surface of the free nappe for four different discharges over the recommended design standpipe crest, and the tank water surface which would result if a total combined flow of 3,200 cfs were passing through the ports and over the top of the pipe.



PROFILE ALONG ℄ OF POWER CONDUIT

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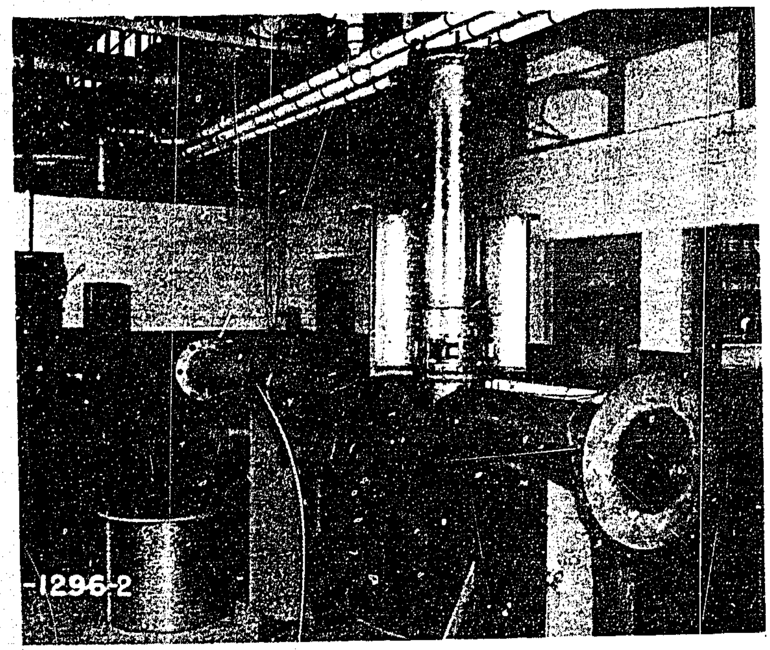
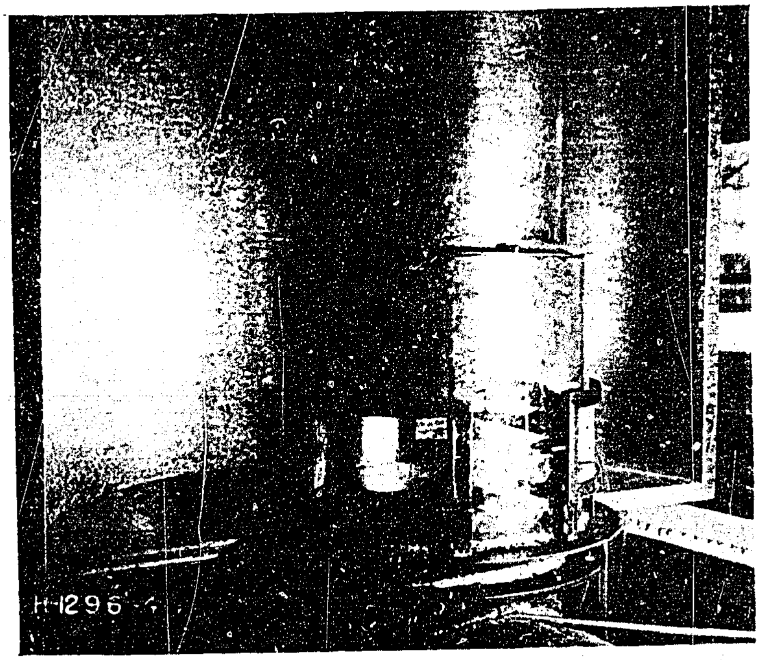
TRINITY RIVER DIVISION

CLEAR CREEK POWER CONDUITS
SURGE TANK

GENERAL ARRANGEMENT

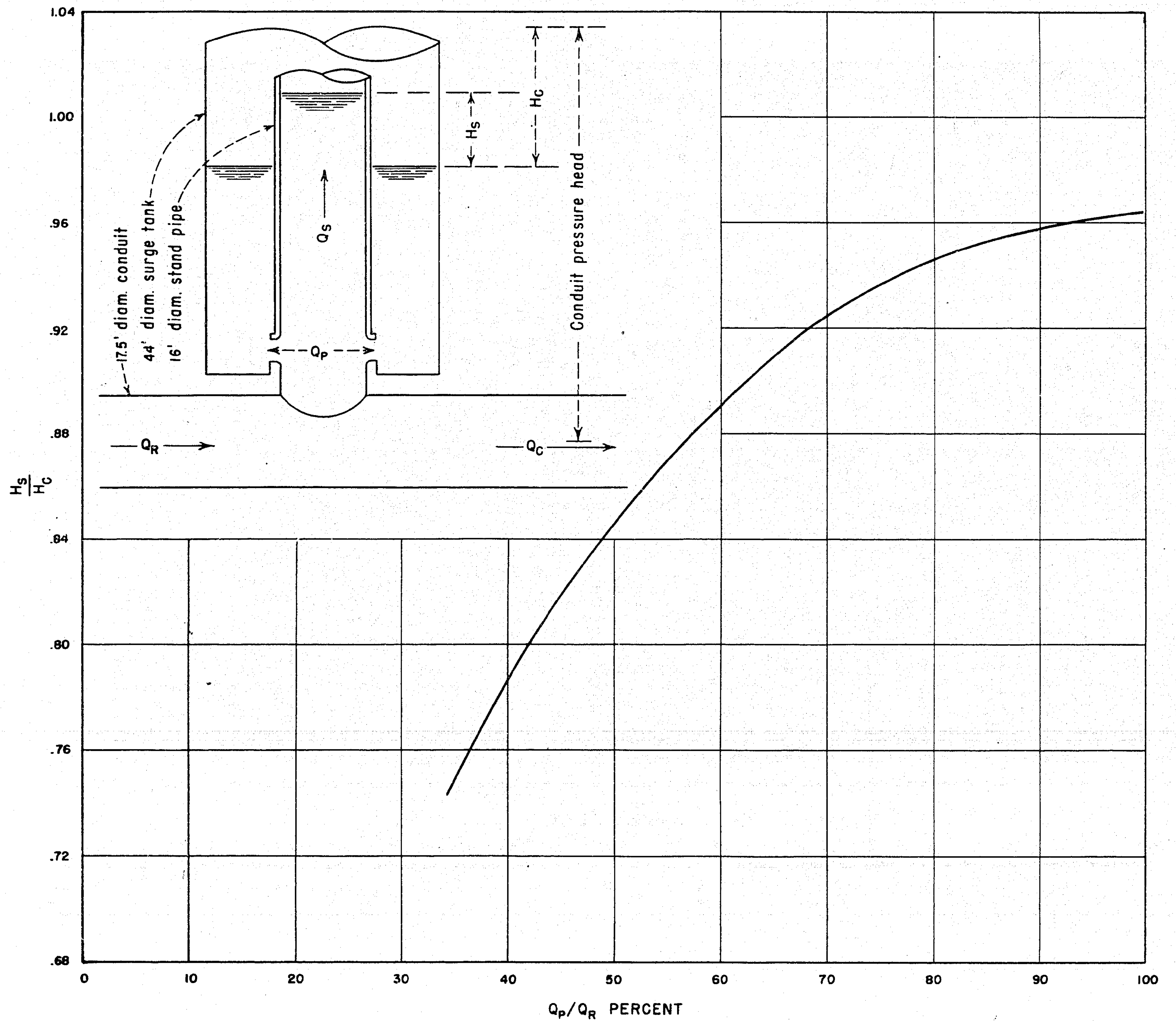


A Laboratory installation (with one-half surge tank floor and wall removed).



B Closeup of ports.

CLEAR CREEK POWER CONDUIT--SURGE TANK
Air Model of the Surge Tank Ports



Q_R — Flow entering system from reservoir.
Q_C — Flow leaving system through conduit.
Q_P — Flow through ports.
Q_S — Flow in stand pipe.

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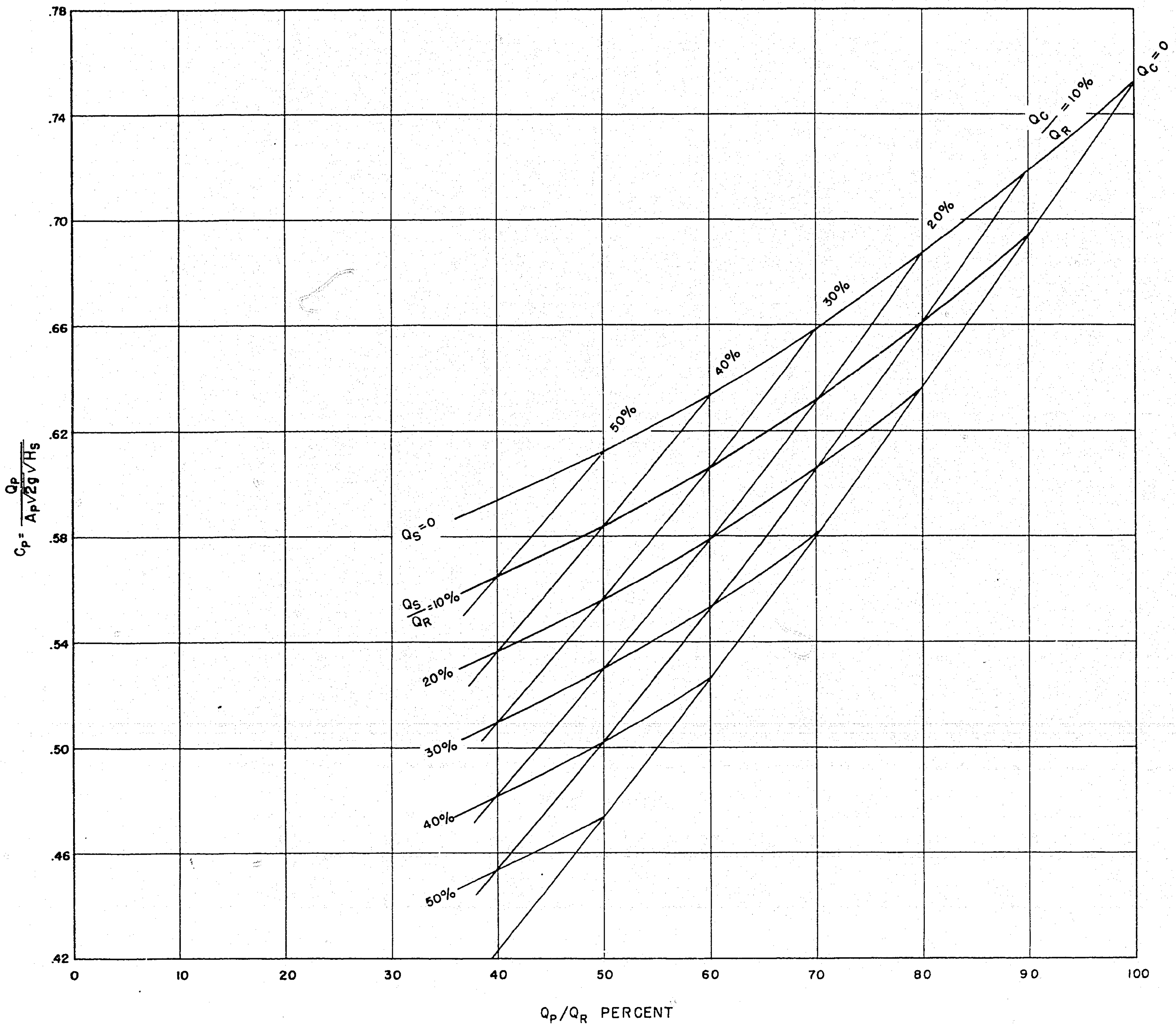
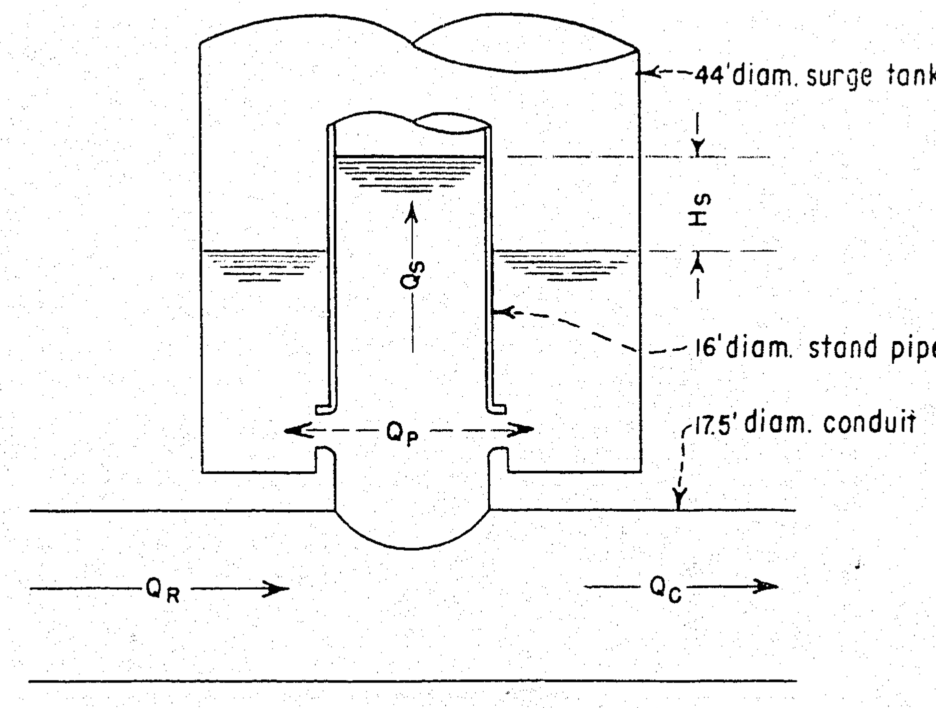
CLEAR CREEK POWER CONDUITS
SURGE TANK PORTS

RATIO OF HEAD DROP FROM STAND PIPE TO TANK AND FROM CONDUIT TO TANK FOR VARIOUS CONDITIONS OF FLOW FROM THE CONDUIT TO THE SURGE TANK

AIR MODEL TESTS





$Q_P = C_P A_P \sqrt{2gH_S}$

Note: For PORT details see figure 6.

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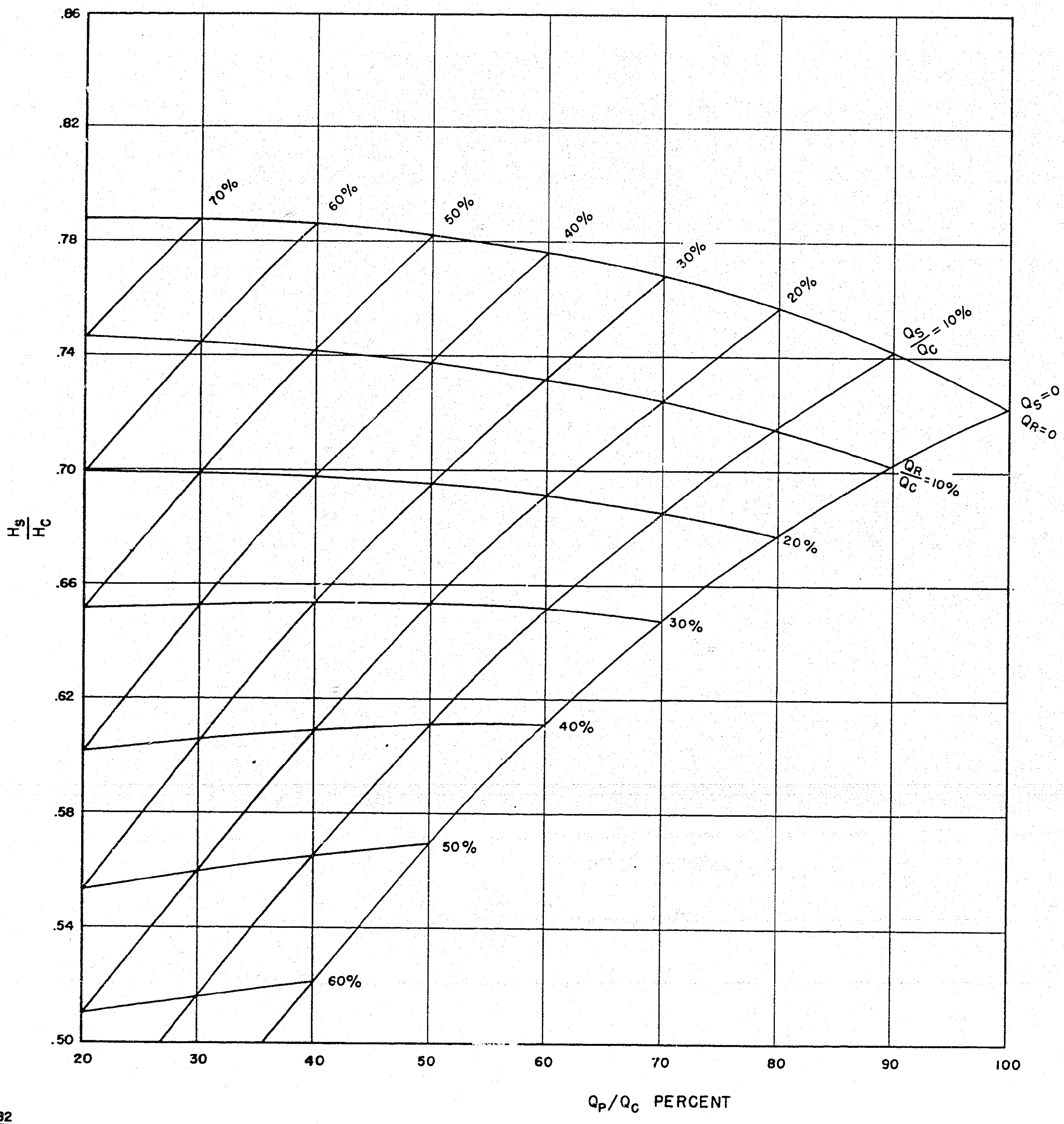
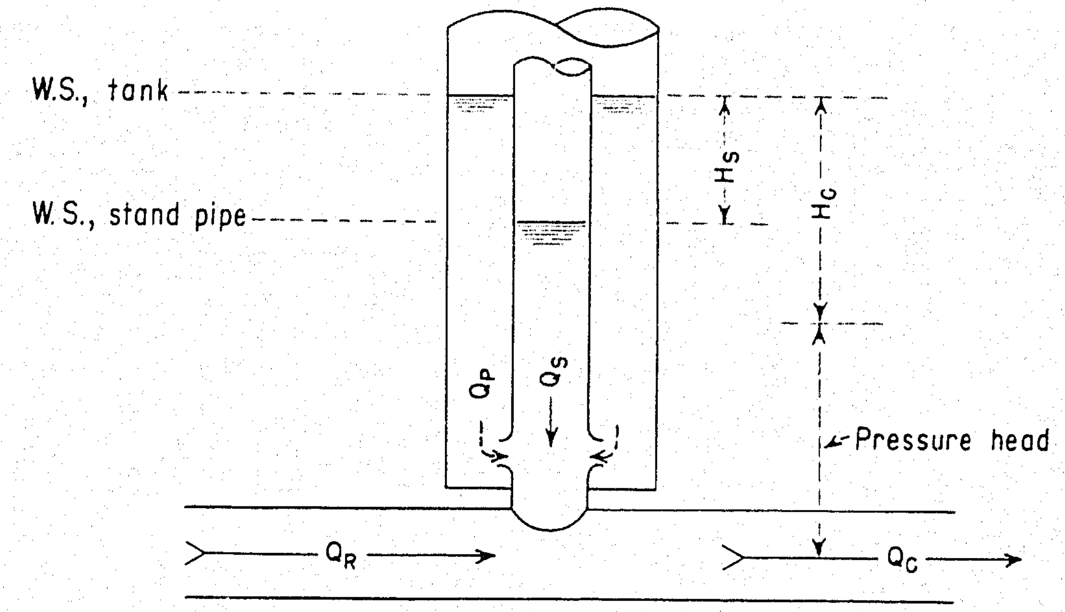
CLEAR CREEK POWER CONDUITS SURGE TANK PORTS

PORT DISCHARGE COEFFICIENTS FOR VARIOUS CONDITIONS OF FLOW FROM CONDUIT TO THE SURGE TANK

AIR MODEL TESTS

582





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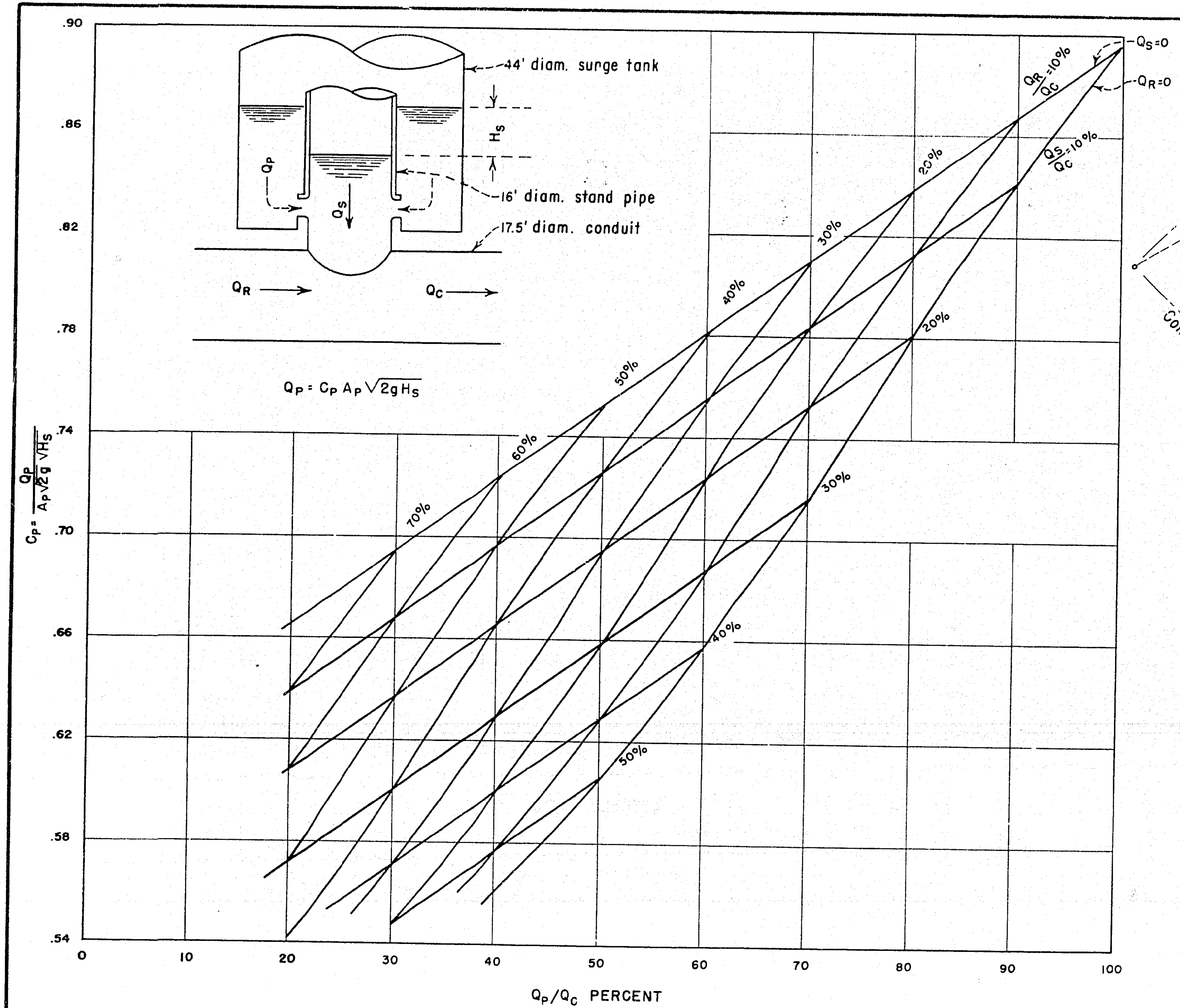
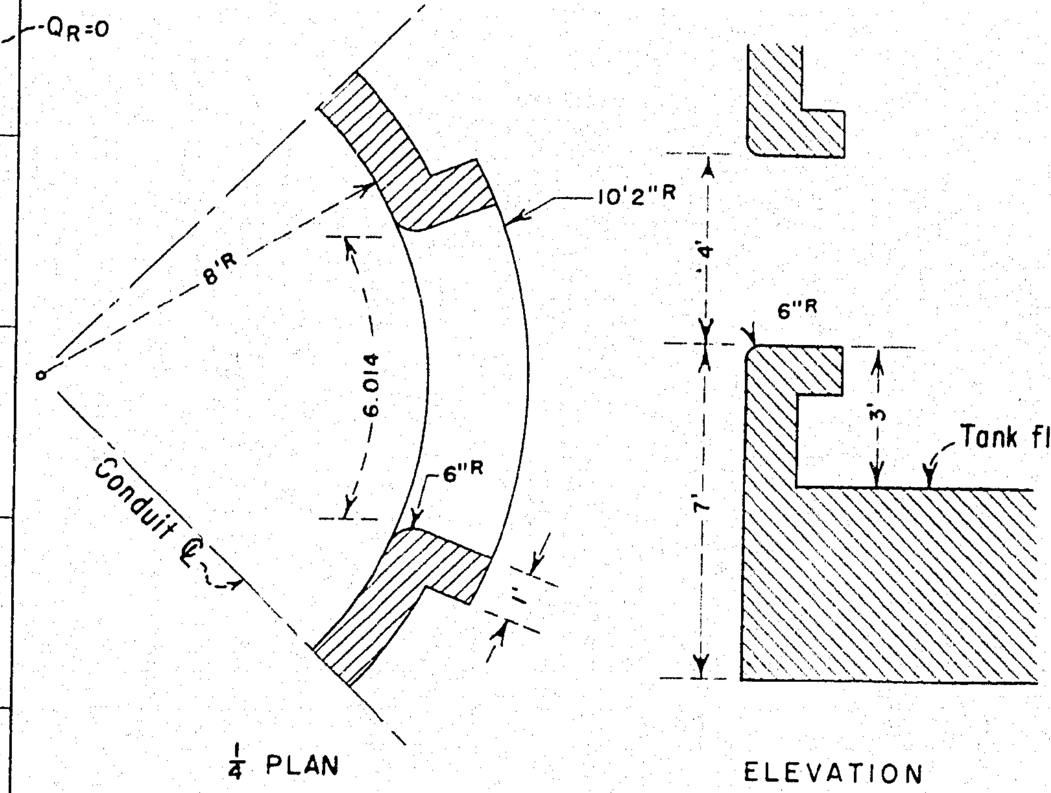
CLEAR CREEK POWER CONDUITS
SURGE TANK PORTS

RATIO OF HEAD DROP FROM TANK TO STAND PIPE AND TANK TO CONDUIT FOR VARIOUS CONDITIONS OF FLOW FROM THE SURGE TANK TO THE CONDUIT

AIR MODEL TESTS





$A_P = (4)(6.014)(4) = 96.224^{\square\,'}$

PORTS
(As tested)

CENTRAL VALLEY PROJECT – CALIFORNIA
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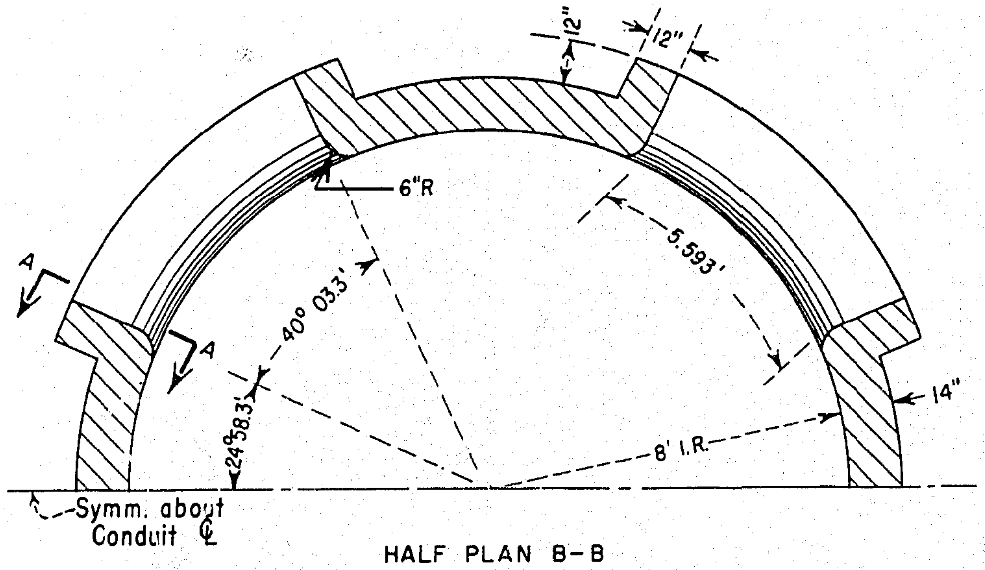
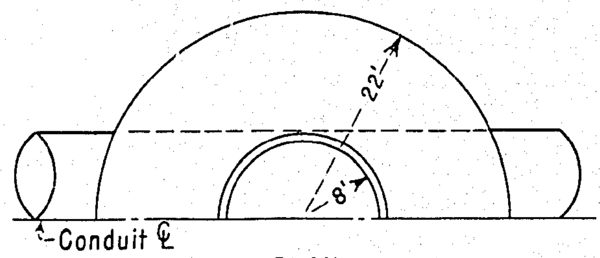
CLEAR CREEK POWER CONDUITS
SURGE TANK PORTS

DISCHARGE COEFFICIENTS FOR VARIOUS CONDITIONS OF FLOW FROM THE TANK TO THE CONDUIT

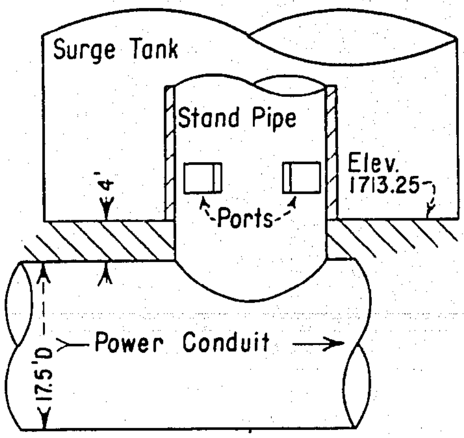
AIR MODEL-TESTS



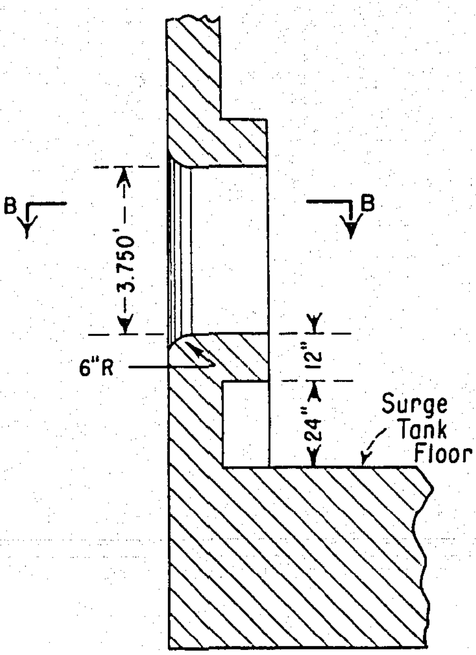
HALF PLAN B-B
THROUGH THE PORTS



PLAN



ELEVATION



SECTION A-A

INTERSECTION OF CONDUIT AND SURGE TANK

Note: Total area of ports= 83.895 sq. ft.

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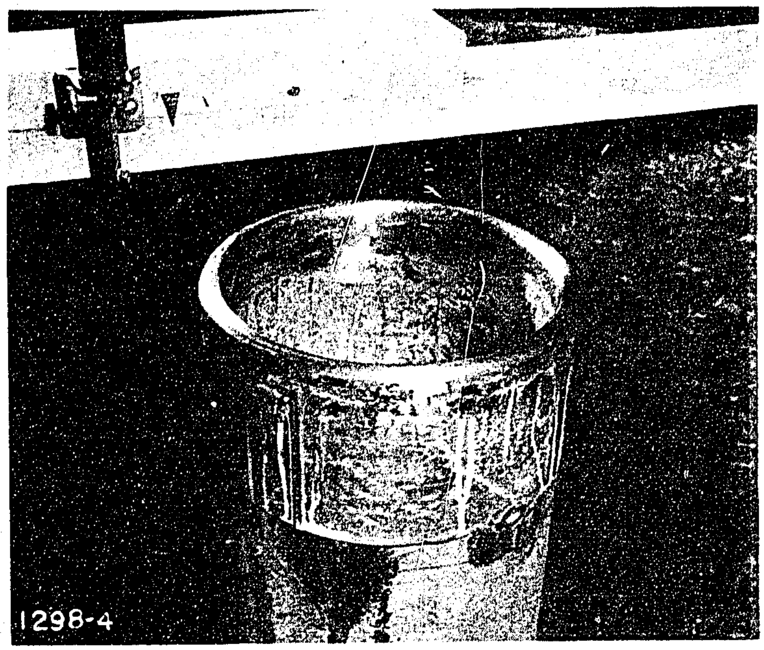
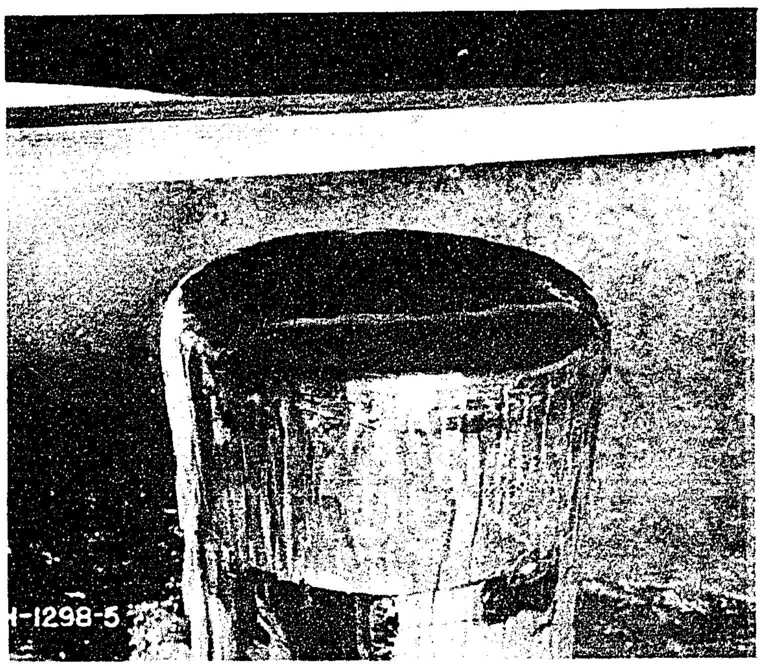
CLEAR CREEK POWER CONDUITS
SURGE TANK

RECOMMENDED PORT DIMENSIONS
AIR MODEL TESTS

582



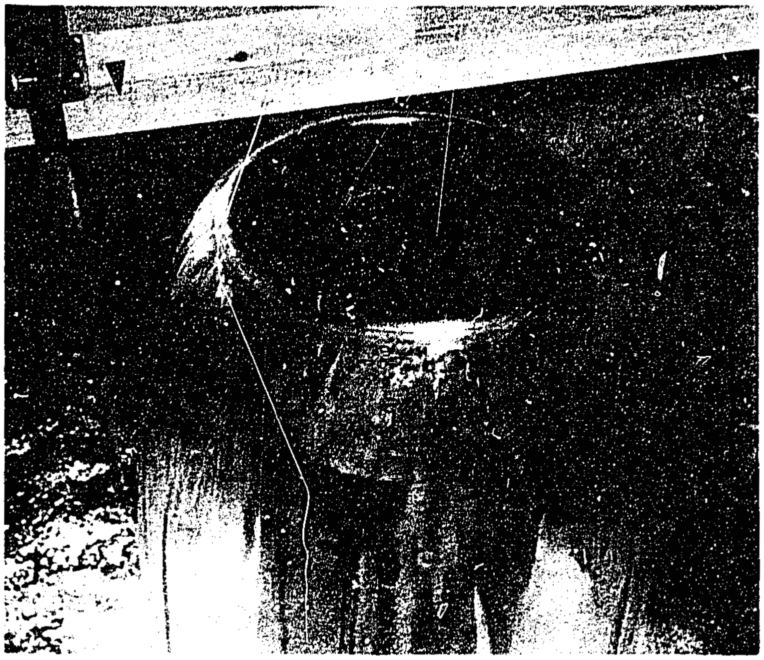
A Top of standpipe.



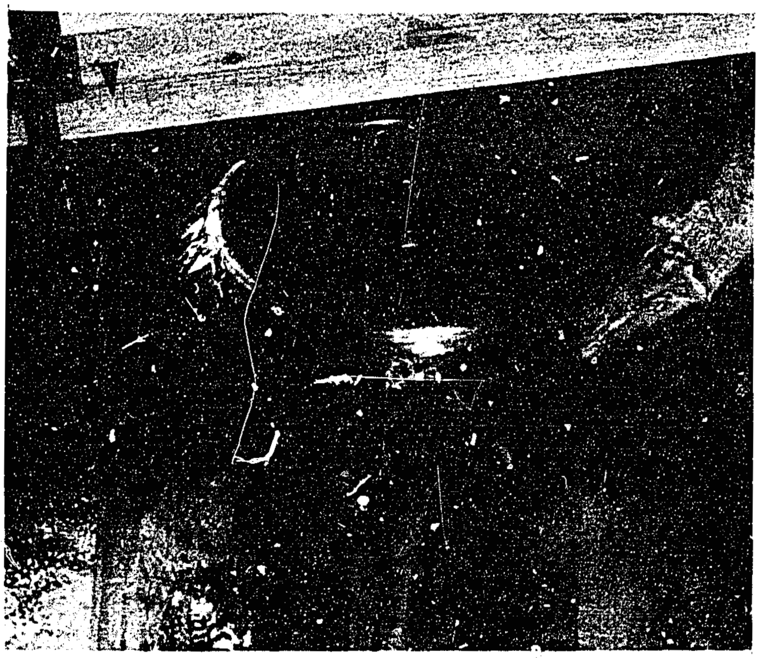
B Q = 815 cfs, clinging to walls of standpipe.

CLEAR CREEK POWER CONDUIT--SURGE TANK
Flow not aerated at top of Standpipe--Preliminary Design
1:18 scale model

Figure 9

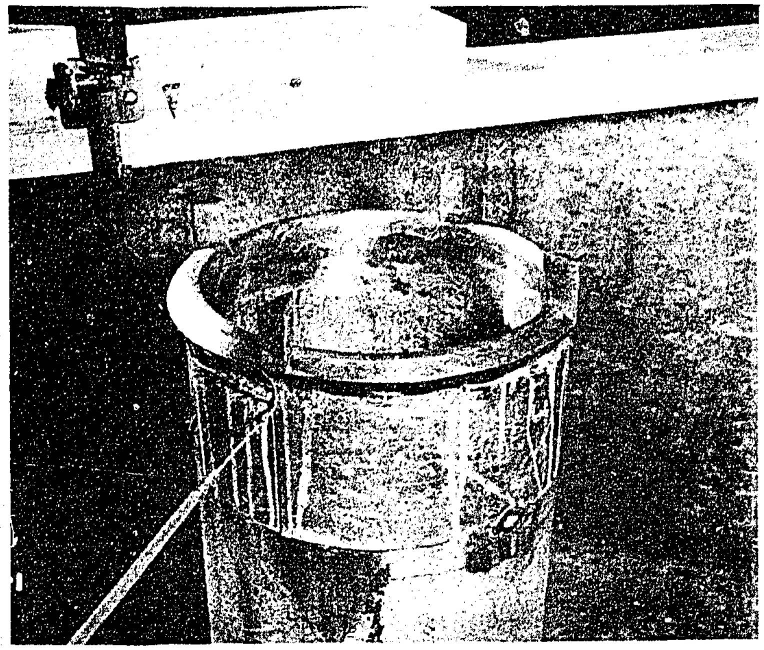


A Q = 815 cfs with unbroken nappe to the surge tank water surface. Note point gage.

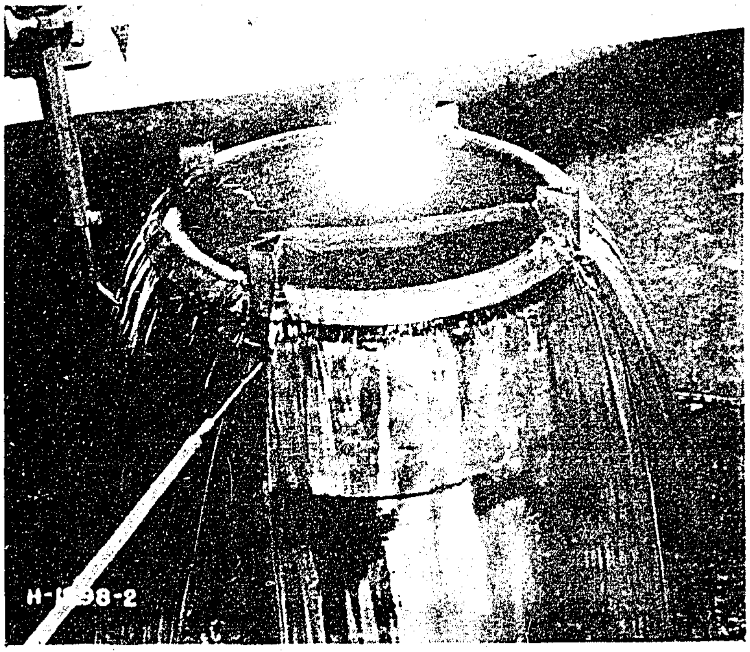


B Q = 815 cfs, nappe fully aerated. Point gage is at same location as in A above.

CLEAR CREEK POWER CONDUIT--SURGE TANK
Effect of aerating flow at top of Standpipe--Preliminary Design
1:18 scale model

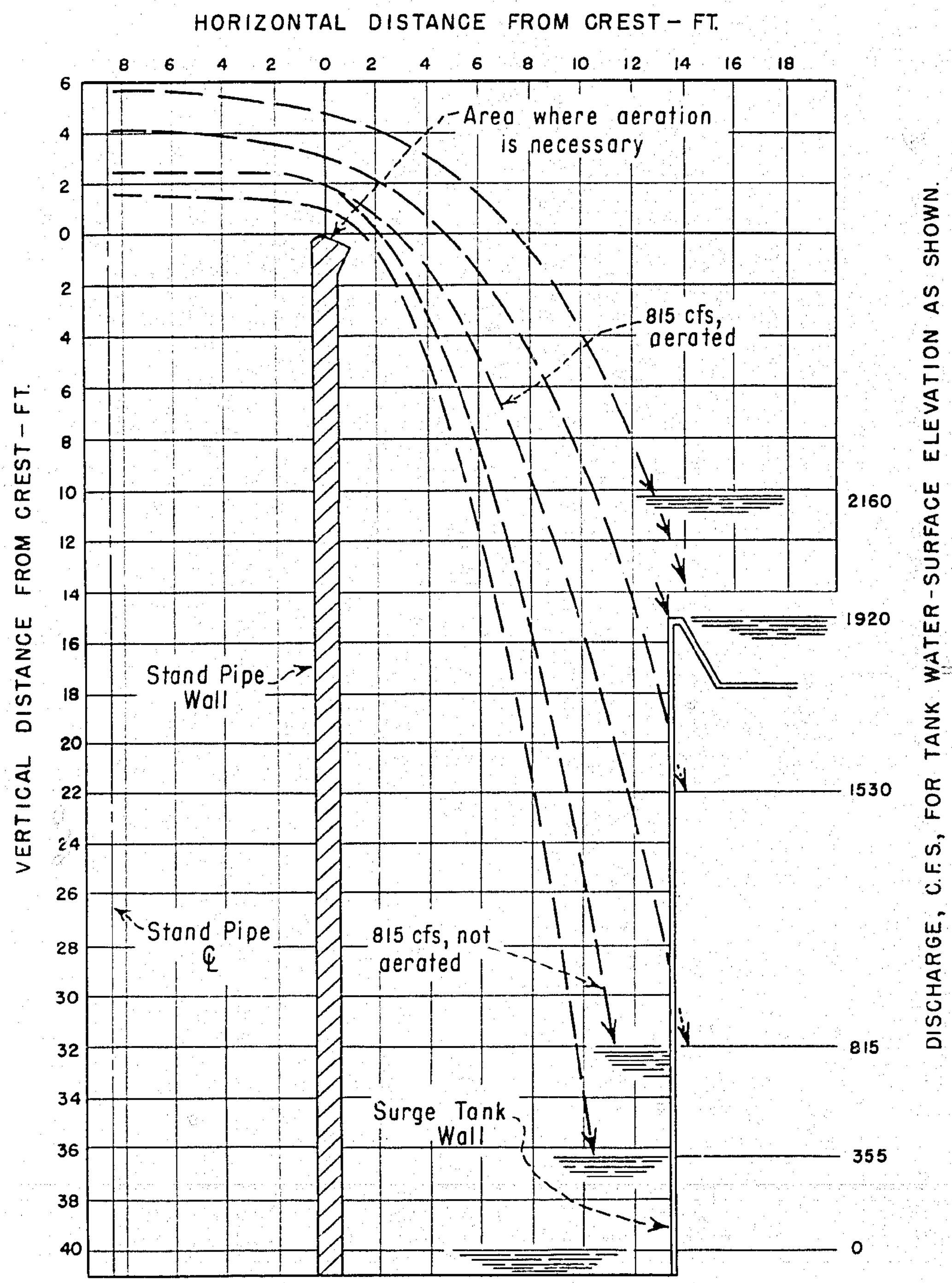


A Recommended design.



B Q = 815 cfs.

CLEAR CREEK POWER CONDUIT--SURGE TANK
Flow at top of Standpipe--Recommended Design
1:18 scale model



Note: Total flow = 3200 cfs, remainder flows through the ports.

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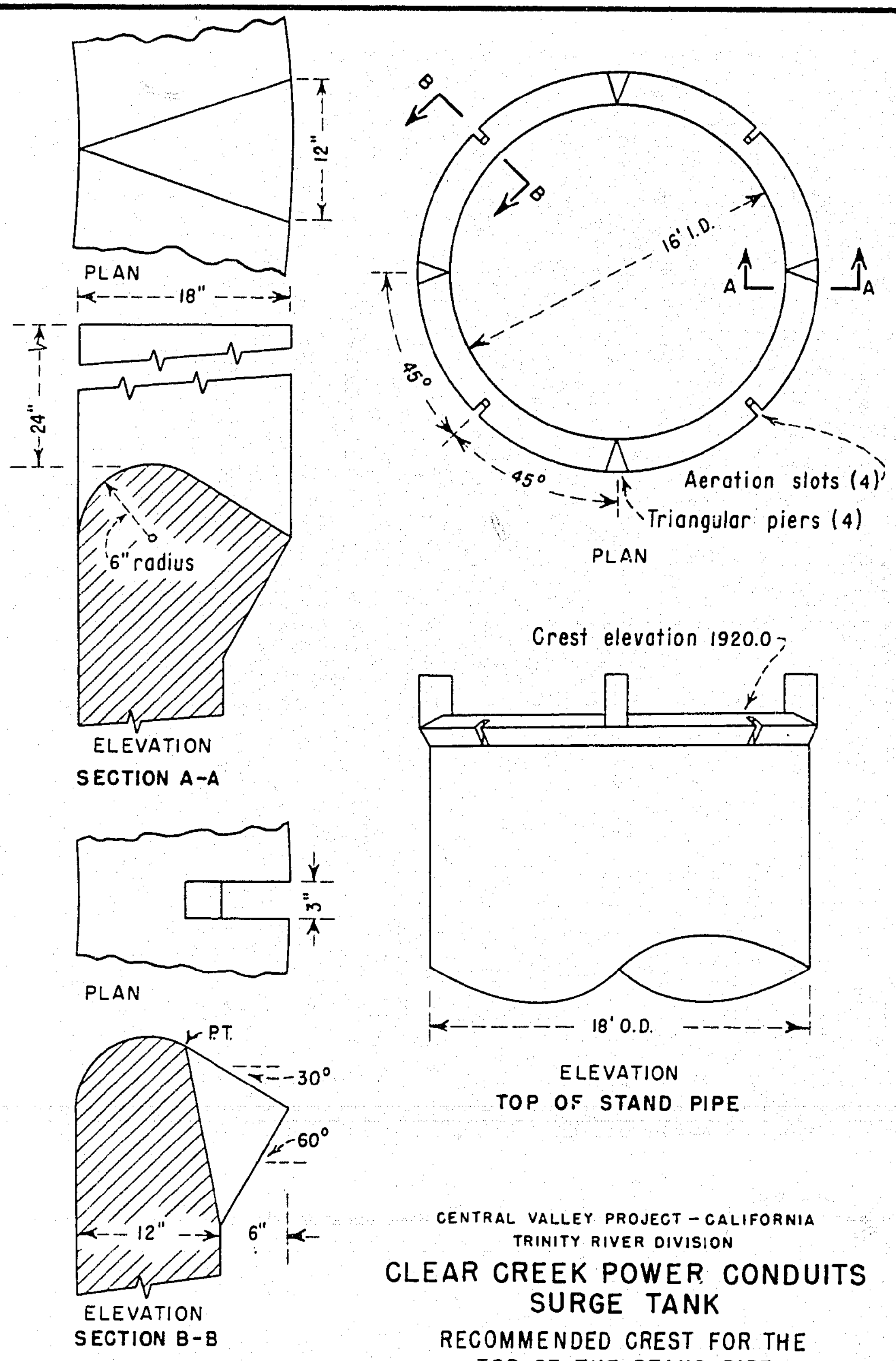
CLEAR CREEK POWER CONDUITS
SURGE TANK

WATER SURFACE PROFILES FOR FLOW OVER THE TOP OF THE STAND PIPE RECOMMENDED DESIGN

1:18 SCALE MODEL



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CLEAR CREEK POWER CONDUITS
SURGE TANK

RECOMMENDED CREST FOR THE TOP OF THE STAND PIPE

1:18 SCALE MODEL

GPO 848096