PAP-90

Model Studies
Clear Creek Power Conduit Surge Tank
Trinity River Division
Central Valley Project

January 25, 1957

Donald Colgate
Memorandum

Chief, Canals Branch

Chief, Division of Engineering Laboratories

Model studies--Clear Creek power conduit surge tank--Trinity River Division--Central Valley Project

In compliance with your memorandum request dated September 28, 1956, 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 7-1/2-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.

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 surfaces 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:

\[
Q_p = C_p A_p \sqrt{2g} \sqrt{H_a}
\]

where

- \( Q_p \) = the discharge passing through the ports
- \( A_p \) = total area of ports as shown in Figure 6
- \( g \) = acceleration of gravity
- \( H_a \) = 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, sloping downward 30° from the horizontal and 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.
FIGURE 1

156' Square

Max. storage Elev 1926.0
Elev 1920.0
Elev 1905.0
Elev 1902.5
Res Elev 1902.0

Note: Storage capacity between Elev's 1827.0 and 1926.0 is 975,900 cu. ft.

Elev 1827.0 - normal operating W.S. for 3200 cfs through the turbines

- 44' diam surge tank

- 16' I.D. stand pipe

- 17.5' I.D. power conduit

Elev 1691.75 → To power house
→ Approx 56,000' to reservoir

PROFILE ALONG E of POWER CONDUIT

TRINITY RIVER DIVISION - CVP
CLEAR CREEK POWER CONDUIT
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
FIGURE 3

TRINITY RIVER DIVISION - CVP
CLEAR CREEK POWER CONDUIT
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(port)/Q(total) Percent

0 10 20 30 40 50 60 70 80 90 100
Figure 4

- 44' diam surge tank
- 16' diam stand pipe
- 17.5' diam conduit

\[ Q_p = C_p A_p \sqrt{2gH_s} \]

For PORT details see figure 6

CLEAR CREEK POWER CONDUIT SURGE TANK PORTS

Port discharge coefficients for various conditions of flow from conduit to the surge tank

Air model tests
Figure 6

**TRINITY RIVER DIVISION - CVP**

**CLEAR CREEK POWER CONDUIT**

**SURGE TANK PORTS**

Discharge coefficients for various conditions of flow from the tank to the conduit.

Air model tests

<table>
<thead>
<tr>
<th>Q(ports)/Q(total)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>10</td>
<td>10%</td>
</tr>
<tr>
<td>20</td>
<td>20%</td>
</tr>
<tr>
<td>30</td>
<td>30%</td>
</tr>
<tr>
<td>40</td>
<td>40%</td>
</tr>
<tr>
<td>50</td>
<td>50%</td>
</tr>
<tr>
<td>60</td>
<td>60%</td>
</tr>
<tr>
<td>70</td>
<td>70%</td>
</tr>
<tr>
<td>80</td>
<td>80%</td>
</tr>
<tr>
<td>90</td>
<td>90%</td>
</tr>
<tr>
<td>100</td>
<td>100%</td>
</tr>
</tbody>
</table>

**From Reservoir**

- 44' diam. surge tank
- 16' diam. stand pipe
- 17.5' diam. conduit

**Q_p = C_p A_p \sqrt{2g H_5}**

**Q_p**

**C_p = A_p/\sqrt{g H_5}**

1/4 PLAN

102" R

6" R

Tank floor

ELEVATION

4-10-57 Colegate
FIGURE 7

HALF PLAN B-B Through the Ports

PLAN

SECTION A-A

INTERSECTION of CONDUIT AND SURGE TANK

TRINITY RIVER DIVISION - CVP
CLEAR CREEK POWER CONDUIT SURGE TANK

Recommended Port Dimensions
Total area of ports = 83.895 sq.ft.

12-27-56 Colgate
A. Top of standpipe.

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

CLEAR CREEK POWER CONDUIT--SURGE TANK
Top of Standpipe, Preliminary Design
1:18 scale model
A  \( Q = 315 \text{ cfs} \) with unbroken nappe to the surge tank water surface. Note point gage.

B  \( Q = 315 \text{ cfs} \), nappe fully aerated. Point gage is at same location as in A above.

**CLEAR CREEK POWER CONDUIT--SURGE TANK**
Top of Standpipe, Preliminary Design
1:18 scale model
Figure 10

A  Recommended design.

B  \( Q = 815 \text{ cfs} \).

CLEAR CREEK POWER CONDUIT--SURGE TANK
Top of Standpipe, Recommended Design
1:18 scale model
FIGURE II

HORIZONTAL DISTANCE FROM CREST - Ft.

8 6 4 2 0 2 4 6 8 10 12 14 16 18

VERTICAL DISTANCE FROM CREST - Ft.

TRINITY RIVER DIVISION - CVP
CLEAR CREEK POWER CONDUIT - SURGE TANK

Water surface profiles for flow over the top of the standpipe, recommended design.
Total flow: 3200 cfs, remainder flows through the ports

1-18-57 Colgate
Recommended crest for the top of the stand pipe
Hydraulic model scale 1:18