Bradley

HYDRAULICS BRANCH
OFFICIAL FILE COPY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF METHODS TO DISSIPATE THE HIGH-VELOCITY JET FROM THE REGULATING VALVE IN TECOLOTE TUNNEL-- SANTA BARBARA PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd.-287

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

February 13, 1951

CONTENTS

	Page
Purpose	1
Conclusions	1
Recommendations	2
Introduction	2
The Investigation	3
The Model	3
The Stilling Basin	3
Tunnel Baffles	4
Single baffle	4
Two baffles	4
Two baffles and a valve flow guide	4
Pressures in flow guide	5
Muffler Type Stilling Device	5

FIGURE LIST

	Figure
Location Map	1
Gate Chamber and Elevator Shaft, Sections and Details	2
Valve of the 1:10 Scale Model Discharging into Tunnel with no Provision for Stilling the High Velocity Jet	3
Stilling Basin with Baffle Piers--Optimum Design	4
Operation of the 1:10 Scale Model with the Optimum Design Stilling Basin with Baffle Piers	5
Final Design--Tunnel Baffles and Valve Flow Guide	6
Operation of the 1:10 Scale Model of the Final Design Tunnel Baffle Arrangement	7
1:10 Scale Models	8
Operation of 1:10 Scale Model of Stilling Basin Designs--without Baffle Piers	9
Representative Tunnel Baffles	10
Operation of 1:10 Scale Model of Tunnel Baffle Designs with Flow of 100 cfs and 104 Feet Head on Valve	11
Pressures in Flow Guide--Final Outlet Design	12
Proposed Muffler Type Stilling Device	13
Operation of a 1:10 Scale Model of a Muffler Type Stilling Device	14

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Research and Geology Division
Denver, Colorado
February 13, 1951

Laboratory Report No. 287
Hydraulic Laboratory
Compiled by: L. R. Thompson
Reviewed by: W. C. Case
J. W. Ball

Subject: Hydraulic model studies of methods to dissipate the high-velocity jet from the regulating valve in Tecolote Tunnel--Santa Barbara Project, California

PURPOSE

To determine the most suitable method of dissipating the energy in the jet from the regulating valve to obtain smooth, free flow in the tunnel into which it discharges.

CONCLUSIONS

1. Two methods, equally satisfactory from a hydraulic viewpoint, to dissipate the valve jet energy are:

(a) A rectangular stilling basin containing floor blocks, with optimum dimensions as shown in Figures 4 and 5.

(b) Two baffles in the tunnel downstream from the valve in combination with a "flow guide" on the valve (Figures 6 and 7).

2. For both methods the jet from the valve must be completely submerged for satisfactory operation.

3. There is no significant difference in the flow pattern whether a needle, tube, or a butterfly valve of the pivot type is used.

4. No objectionable subatmospheric pressures are present in the valve flow guide of method 1 (b) as evidenced by the lowest recorded pressure of 1.25 feet of water above atmosphere at 25 cfs discharge and 104 feet head on the valve (Figure 12).

5. At the maximum discharge of 100 cfs, the valve discharges against a head of 9 feet of water at the valve centerline when the stilling-basin is used, and 5 feet of water when the flow guide and two tunnel baffles are used.

6. With regard to the tunnel baffles, the optimum open area in the upstream baffle is about twice the area of the jet, or one-fourth the area of the tunnel. Best results are obtained with the openings uniformly distributed over the baffle (Figure 6). The downstream baffle should be in the shape of a weir with the crest near the horizontal centerline of the tunnel to insure adequate submergence of the valve jet at low discharges.

7. The muffler type stilling device (Figures 13 and 14) has many desirable characteristics which merit its consideration for future installations. Further study is required to establish its practicability and optimum dimensions.

RECOMMENDATIONS

1. Use the jet dissipation method utilizing tunnel baffles and a flow guide. It will require less excavation than the stilling basin; the valve will not have to be lowered below the elevation of the tunnel, which would require a bend in the pipe upstream of the valve; and the valve will discharge against a slightly lower head.

2. Vent the tunnel immediately downstream from the downstream baffle to insure an adequate air supply to the tunnel.

INTRODUCTION

Tecolote Tunnel, approximately 6.4 miles long, is a 7-foot-diameter, horseshoe-shaped tunnel outlet for the Cachuma Reservoir of the Santa Barbara Project (Figure 1). Its purpose is to supply supplemental domestic water to the city of Santa Barbara, California, and to add to the irrigation water supply for approximately 30,000 acres of land.

An operating chamber, housing a venturi type meter and the regulating valve, is located in the 7-foot horseshoe tunnel about 800 feet from the inlet. Figure 2 shows the final design which incorporates the model test results.

The outlet is required to release a maximum flow of 100 cfs between heads of 20 and 104 feet and is expected to operate at various heads and quantities between these limits.

If the jet from the valve was admitted directly into the tunnel as shown in Figure 3, the tunnel walls might be damaged or undesirable waves might occur downstream. Hydraulic model studies were made to evolve some means of stilling the high-velocity jet from the valve such that the flow would pass smoothly through the tunnel at subcritical velocity. The stilling process involves a pressure recovery from the velocity head of the jet and an energy dissipation in the form of friction between the jet and slow-moving water into which the jet discharges. A system

designed to accomplish this process would have to include (1) a flow area greater than that of the jet to permit a reduction in velocity, (2) a restriction of the flow to provide sufficient backwater to keep the jet submerged at all heads and discharges, and (3) some means of dispersing the jet to distribute the velocity, and increase the turbulence and eddy losses.

Members of the Canals Division, Mechanical Division and the Hydraulic Laboratory of the Research and Geology Division collaborated in developing the final design on the basis of the results of the hydraulic model studies discussed in this report.

THE INVESTIGATION

The Model

A 1:10 scale model was constructed to include the regulating valve, a stilling basin, and 200 feet of the 7-foot-diameter horseshoe tunnel downstream from the valve (Figure 8). A 3.2-inch-inlet-diameter tube valve, a 3.0-inch-inlet-diameter needle valve and a 3.0-inch butterfly, pivot-type valve were used in the model tests. The stilling basin consisted of a box 8.4 inches wide with an adjustable floor and ends so that the length and depth of the stilling basin could be varied. One side of the box was made of glass to permit observation of the flow conditions in the basin. The model tunnel was an 8.4-inch-diameter horseshoe pipe made of transparent plactic in sections 6, 12, and 24 inches long. The stilling basin could be removed entirely so the valve could discharge through a flow guide directly into the tunnel. With this arrangement, baffles made of 16-gage steel were bolted between the flanges of the plastic pipe to give the effect of a stilling basin in the tunnel. One section of tunnel was fitted with a standpipe to determine the effect of venting. Tail-water elevation was controlled by an adjustable weir plate on the end of the tunnel. Discharge was measured with an orifice meter, and the head on the valve was measured with a mercury manometer.

The Stilling Basin

The model stilling basin lengths represented prototype lengths varying from 22 to 76 feet and prototype depths from floor to tunnel invert of 5 to 15 feet. Without physical aids such as floor blocks no practicable combination of length and depth gave desirable flow conditions (Figure 9). Blocks of various shapes and spacings installed on the basin floor improved the stilling action; but all deflected some water vertically, giving rise to boils and surface rolls. Finally, a "flow guide" consisting of three triangular blocks, surmounted by a cover plate to control the vertical flow, was developed, which gave a very smooth water surface at all heads and discharges. This arrangement with the most satisfactory stilling-basin dimensions is shown in Figures 4 and 5.

This arrangement was tested with a tube, needle, and pivot-type butterfly valve. The type of valve used made no apparent difference in the stilling action of the model basin. The water level in the basin was 9 feet above the centerline of the valve at the maximum discharge of 100 cfs.

Tunnel Baffles

Single baffle. The possibility of accomplishing the desired stilling action without using a conventional type of stilling basin was next investigated. Baffle plates of varying designs (Figure 10) were tested singly in the tunnel at various locations. In order to get even flow distribution through the baffle, the open area of the baffle had to be in the form of openings spaced uniformly over the face of the baffle. If the open area was made small enough to maintain sufficient backwater to keep the jet submerged at all discharges, the velocity through the baffle plate was high and caused objectionable turbulence immediately downstream from the baffle. Thus, one baffle was insufficient (Figure 11A).

Two baffles. A system of two baffles was evolved which operated well for one particular head and discharge. In this case, the upstream baffle had widely distributed openings that broke up the jet action and gave even flow distribution. Also, the open area was large enough to give appreciable velocity reduction. The second baffle was in the form of a weir to provide the backwater necessary to keep the jet submerged. The weir-type baffle was particularly needed for combinations of high heads and low discharges, since the normal tail-water elevation in the tunnel was low for these discharges. The operating range of the two-baffle system was limited by the amount of open area in the upstream baffle. If the amount of open area was too small, the head against which the valve must discharge became restrictive and the velocity through the baffle was too high (Figure 11B). If the amount of open area was too great, the jet was not sufficiently diffused and flow distribution through the baffle was poor, causing objectionable turbulence downstream from the baffle. Also, too great an open area in the baffles resulted in subatmospheric pressures in the tunnel below the valve, and air was drawn into the tunnel through the standpipe. This served to reduce the submergence of the jet, resulting in even greater turbulence.

Two baffles and a valve flow-guide. It appeared that the satisfactory flow range of the two-baffle system could be greatly increased by securing even velocity distribution before the water reached the upstream baffle. Since a concrete wall separates the valve house from the tunnel downstream, a steel flow-guide, bolted to the valve, extending through the concrete wall and connecting to the tunnel is necessary. Since turbulence in the flow-guide was not considered objectionable, the guide was designed to break up the jet from the valve to obtain better flow distribution of the water into the tunnel. The design developed (Figure 6) was very effective in breaking up the jet action and producing an even flow distribution into the tunnel. This flow-guide, in combination with two baffles in the tunnel, constitutes a stilling device which is effective over

the entire range of heads and discharges anticipated for the Tecolote Tunnel (Figure 7). With this arrangement no air is taken through the standpipe and the water does not rise into the standpipe, indicating atmospheric pressure in the tunnel.

The model studies indicated that the minimum distance between baffles and between the flow-guide and the first baffle is 10 feet. This distance may be increased without adversely affecting flow conditions in the tunnel. The shape of the individual openings in the baffles made no apparent difference; the important feature of each baffle was the amount and the distribution of the open area in the baffle.

Pressures in flow-guide. Pressure readings at points in the flow-guide assembly described above where low pressures were most likely to occur disclosed that no subatmospheric pressures existed (Figure 12). The lowest pressure was 1.25 feet above atmospheric pressure which occurred at 25 cfs discharge and 104 feet head on the valve centerline. The head against which the valve discharged was 5 feet of water on the valve centerline at a discharge of 100 cfs.

Muffler Type Stilling Device

The possibility of developing a muffler type stilling device consisting of two concentric cylinders that could be bolted to the end of a regulating valve was proposed by the Mechanical Division (Figure 13). Since the Tecolote Tunnel model could be readily adapted to testing such a device, a preliminary test was made at this time, and the test results were not intended to be applicable to the Tecolote problem. A sheet metal inner cylinder, closed at the downstream end, 5 feet in diameter, 10 feet long, had four rows of $7\frac{1}{2}$-inch-diameter holes on longitudinal centerlines 90° apart. Each row had four holes spaced 20 inches from center to center; the upstream hole in each row was located 20 inches from the valve end. The inner cylinder was bolted to the tube valve. The outer cylinder shown in Figure 13 was represented by the model plastic tunnel. A slotted baffle plate was installed in the tunnel, 40 feet downstream from the cylinder, to provide tail water which kept the inner cylinder submerged (Figure 14). It appeared from the limited tests made that this arrangement has good possibilities as a stilling device. Further study is warranted where installation of this stilling device may be practicable.

Interior - Reclamation - Denver, Colo.

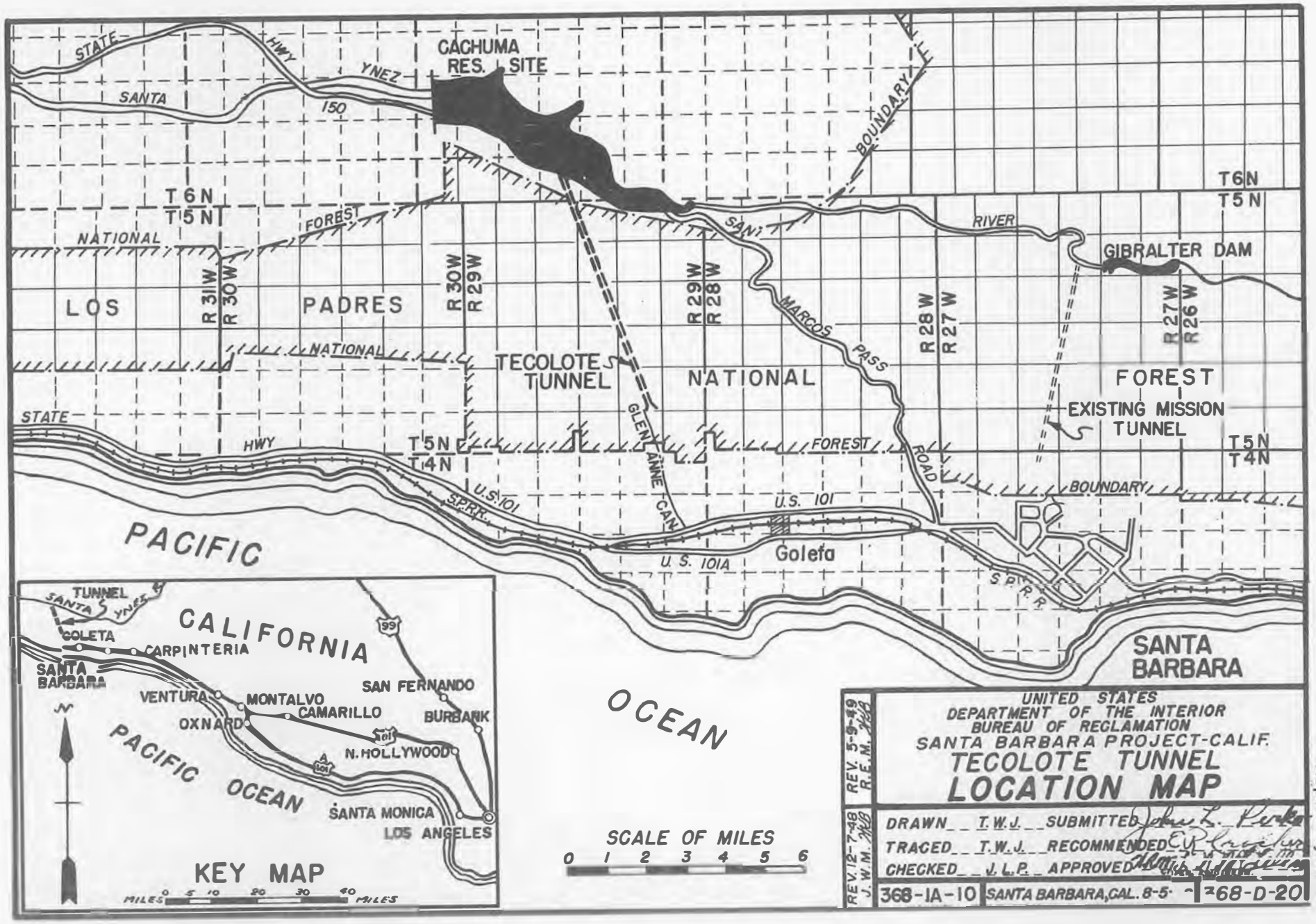
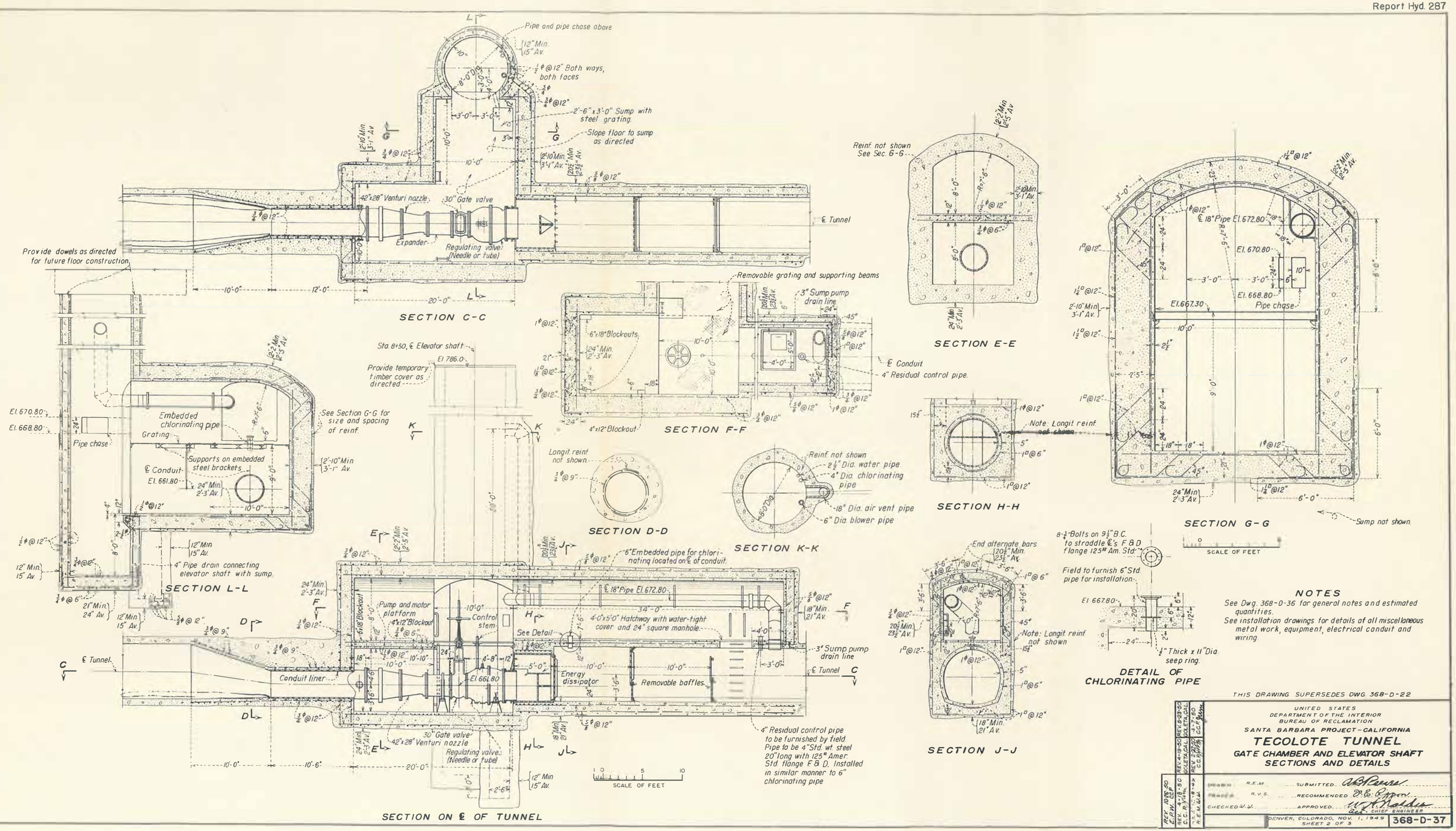


FIGURE I
Report Hyd. 287



NOTES

See Dwg. 368-D-36 for general notes and estimated quantities.

See installation drawings for details of all miscellaneous metal work, equipment, electrical conduit and wiring.

THIS DRAWING SUPERSEDES DWG 368-D-22

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SANTA BARBARA PROJECT—CALIFORNIA

TECOLOTE TUNNEL

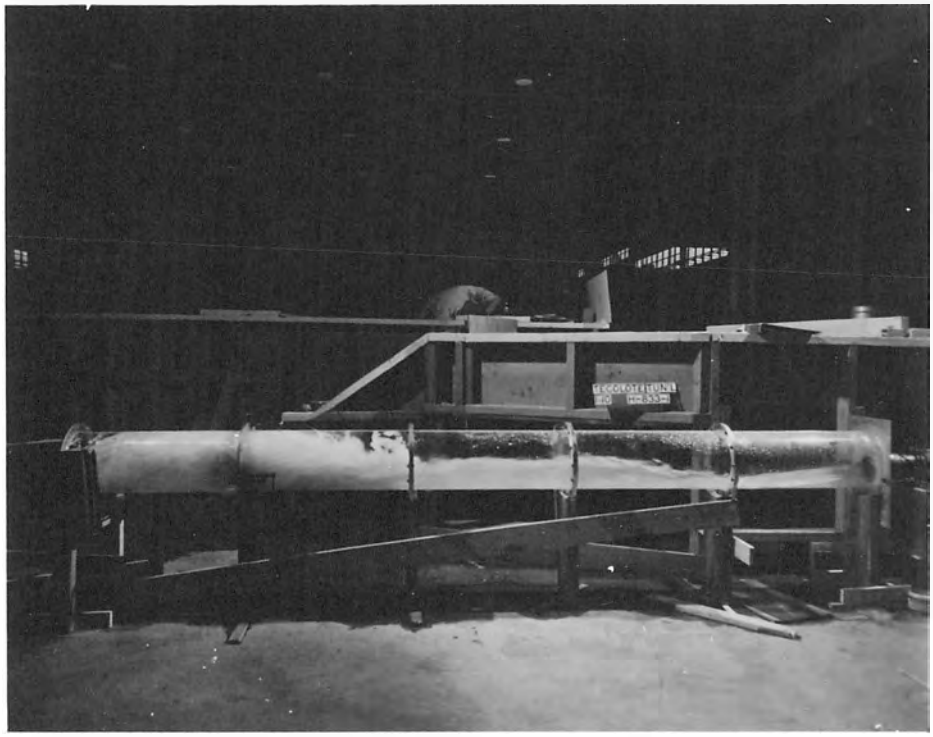
GATE CHAMBER AND ELEVATOR SHAFT SECTIONS AND DETAILS

REV. 10-26-50 E.P.W. C.E.P.
REV. 4-18-50 C.C. R.V.S.H.
REV. 2-23-50 C.L.E. T.A. C.A.L.
REV. 6-2-50 C.L.E. T.A. C.A.L.
REV. 6-8-49 R.E.M. C.E.P.
REV. 6-14-49 R.E.M. C.E.P.

DRAWN R.E.M. SUBMITTED
TRACED R.V.S. RECOMMENDED
CHECKED W.J. APPROVED
Asst. CHIEF ENGINEER

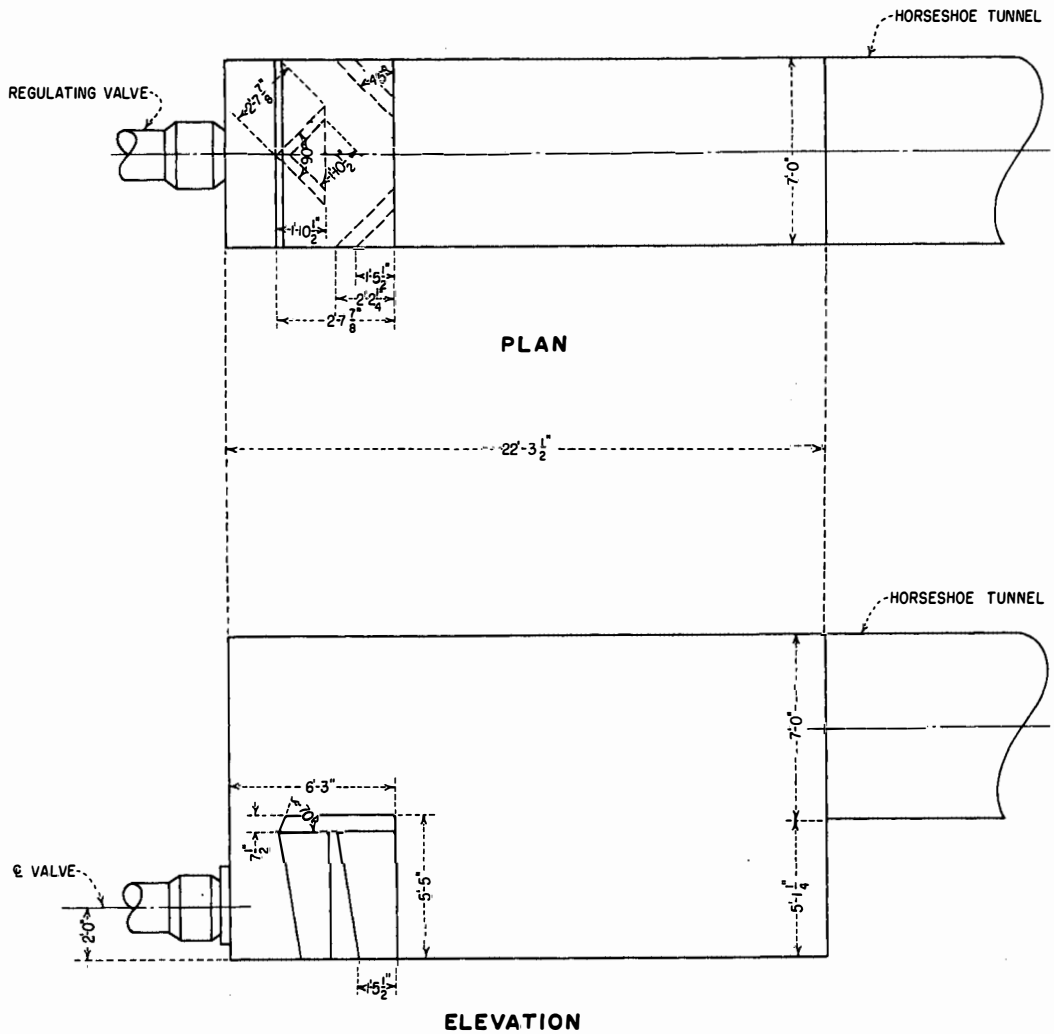
DENVER, COLORADO, NOV. 1, 1949
SHEET 2 OF 3

368-D-37



Jet impinging directly on tunnel lining--
flow 100 cfs. Head on valve 104 feet.

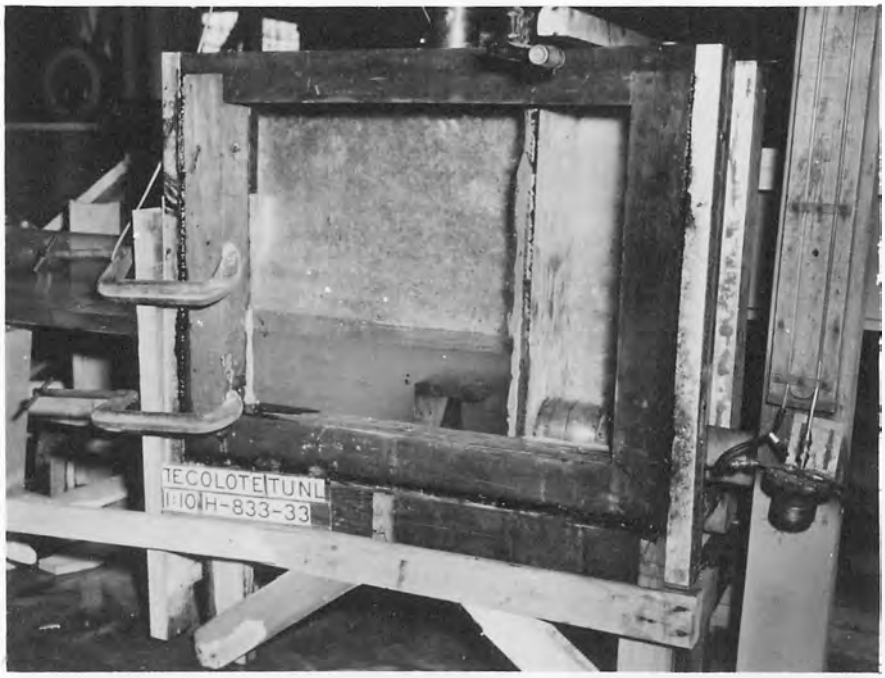
TECOLOTE TUNNEL
Valve of the 1:10 Scale Model discharging into the tunnel
with no provision for stilling the High Velocity Jet.



TECOLOTE TUNNEL

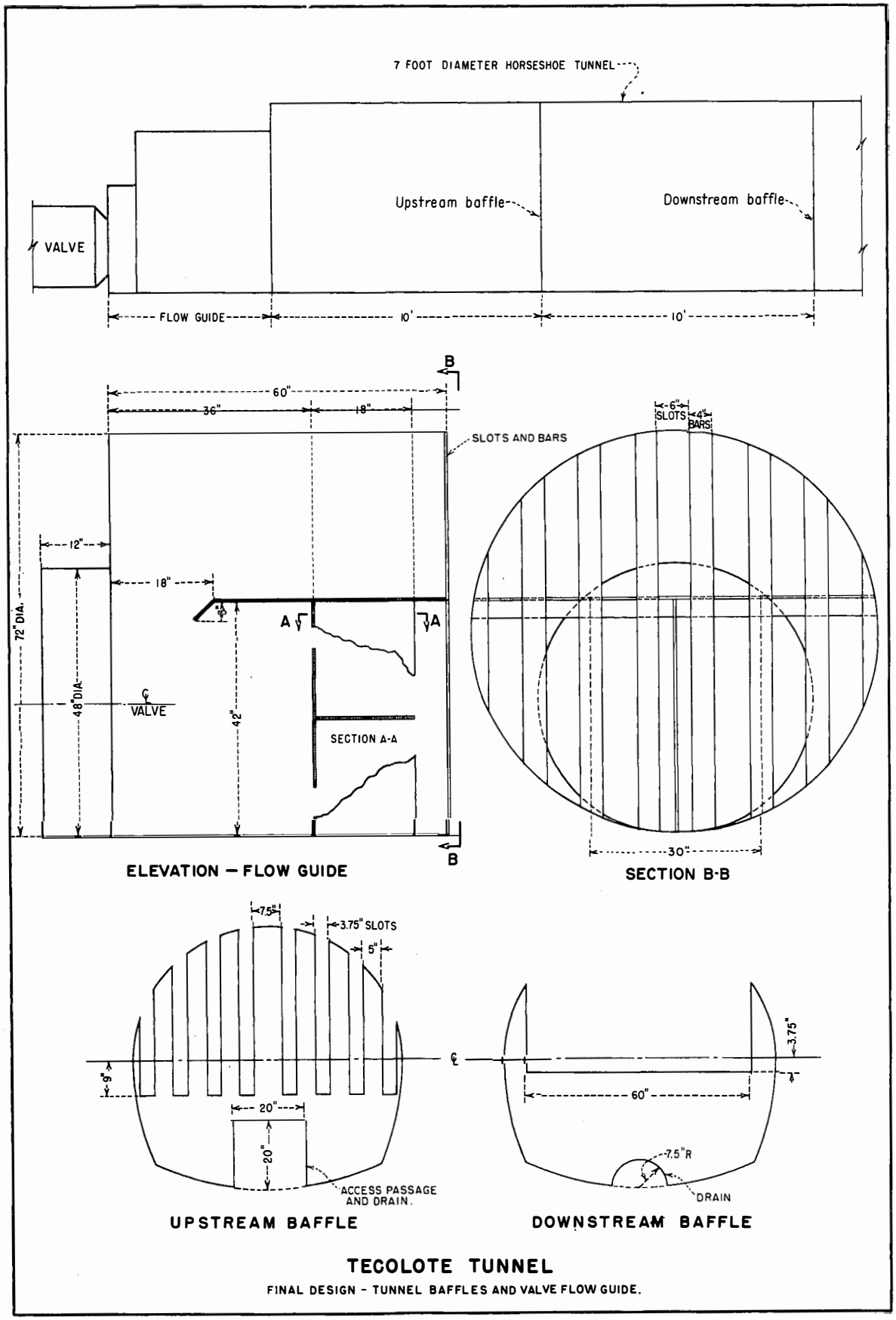
STILLING BASIN WITH BAFFLE PIERS
OPTIMUM DESIGN

A. Flow 100 cfs. Head on valve, 104 feet



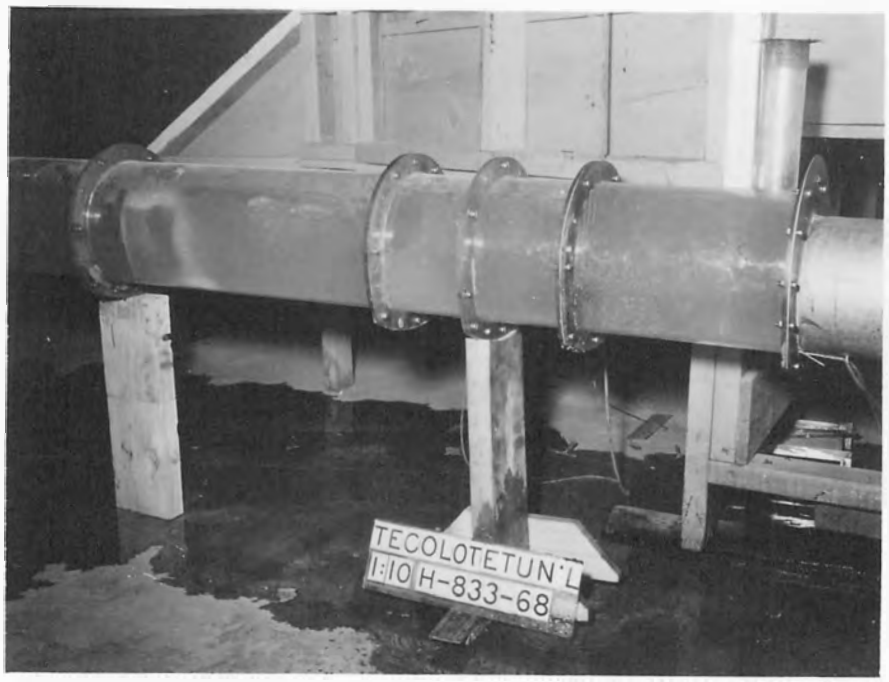
B. Flow 25 cfs. Head on valve 104 feet

TECOLOTE TUNNEL
Operation of the 1:10 Scale Model with Optimum Design Stilling Basin with Baffle Piers.

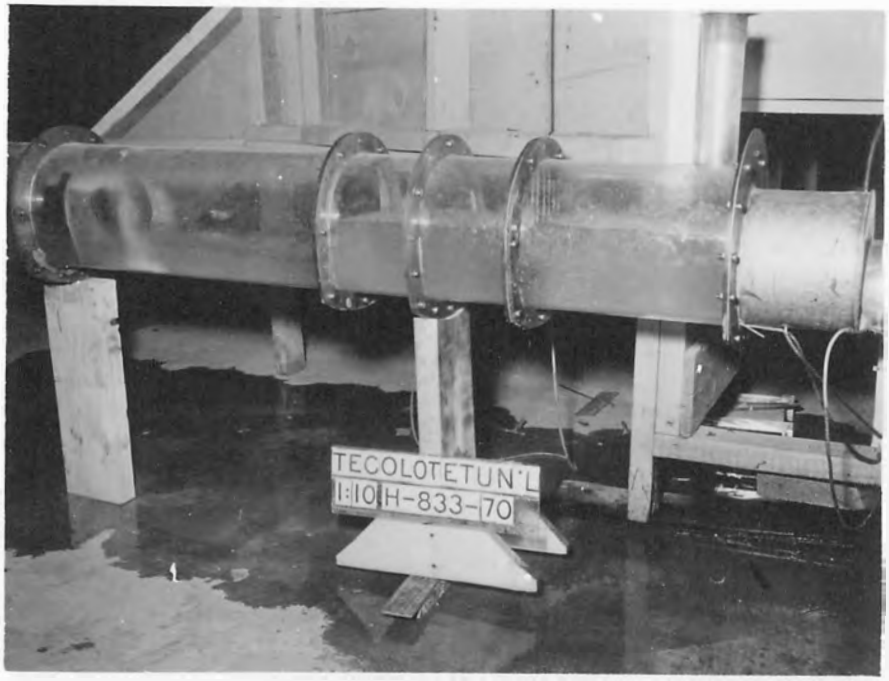


TECOLOTE TUNNEL

FINAL DESIGN - TUNNEL BAFFLES AND VALVE FLOW GUIDE.

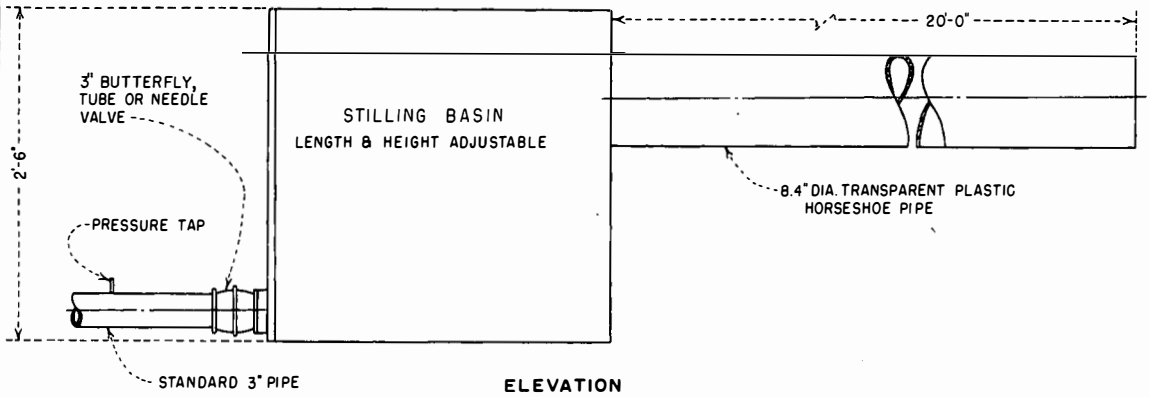


A. Flow 100 cfs. Head on valve, 104 feet



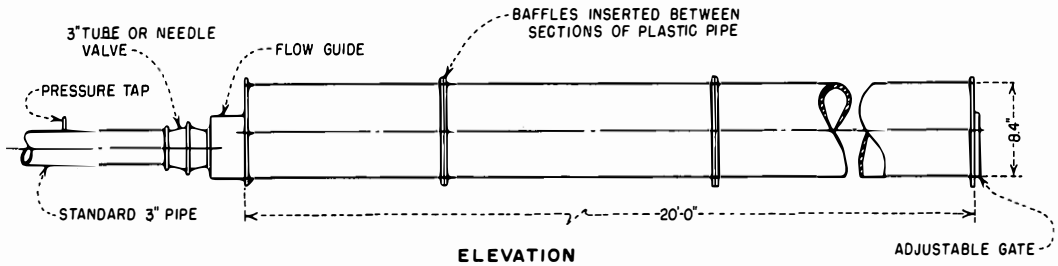
B. Flow 25 cfs. Head on valve, 104 feet

TECOLOTE TUNNEL
Operation of the 1:10 Scale Model of the Final Design Tunnel Baffle Arrangement.



ELEVATION

STILLING BASIN MODEL

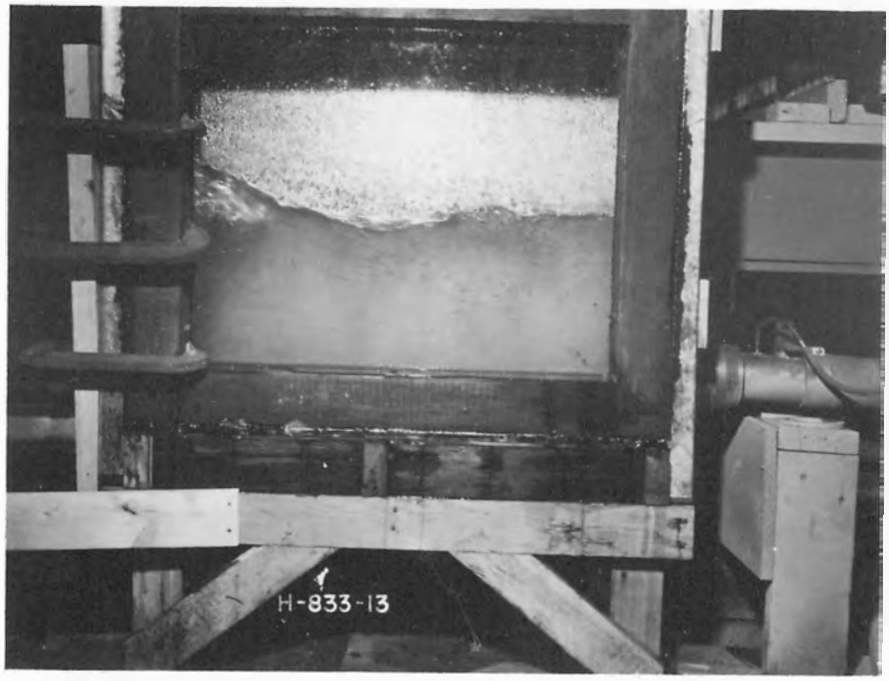


ELEVATION

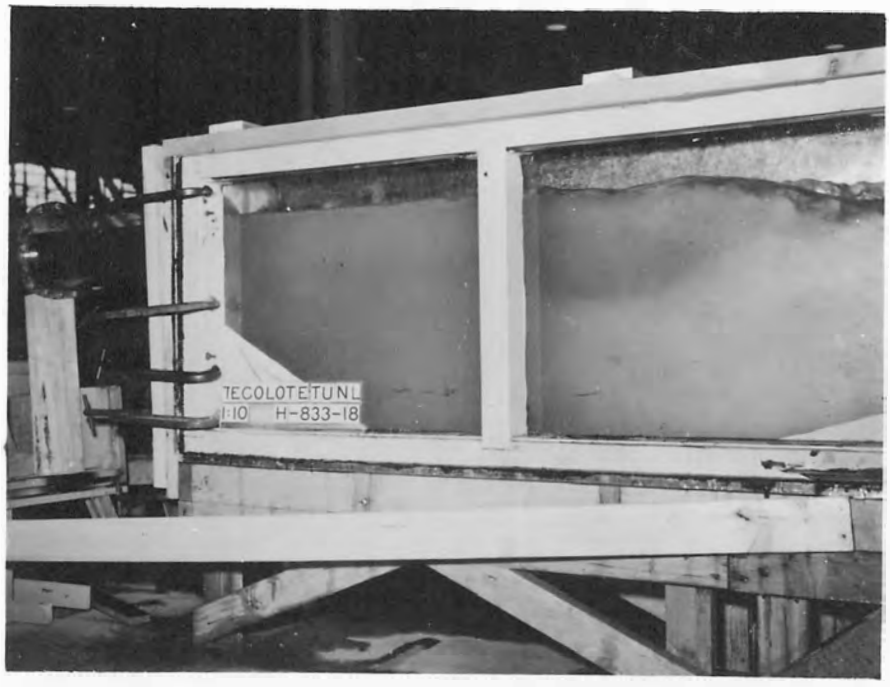
TUNNEL BAFFLE MODEL

TECOLOTE TUNNEL

1:10 SCALE MODELS

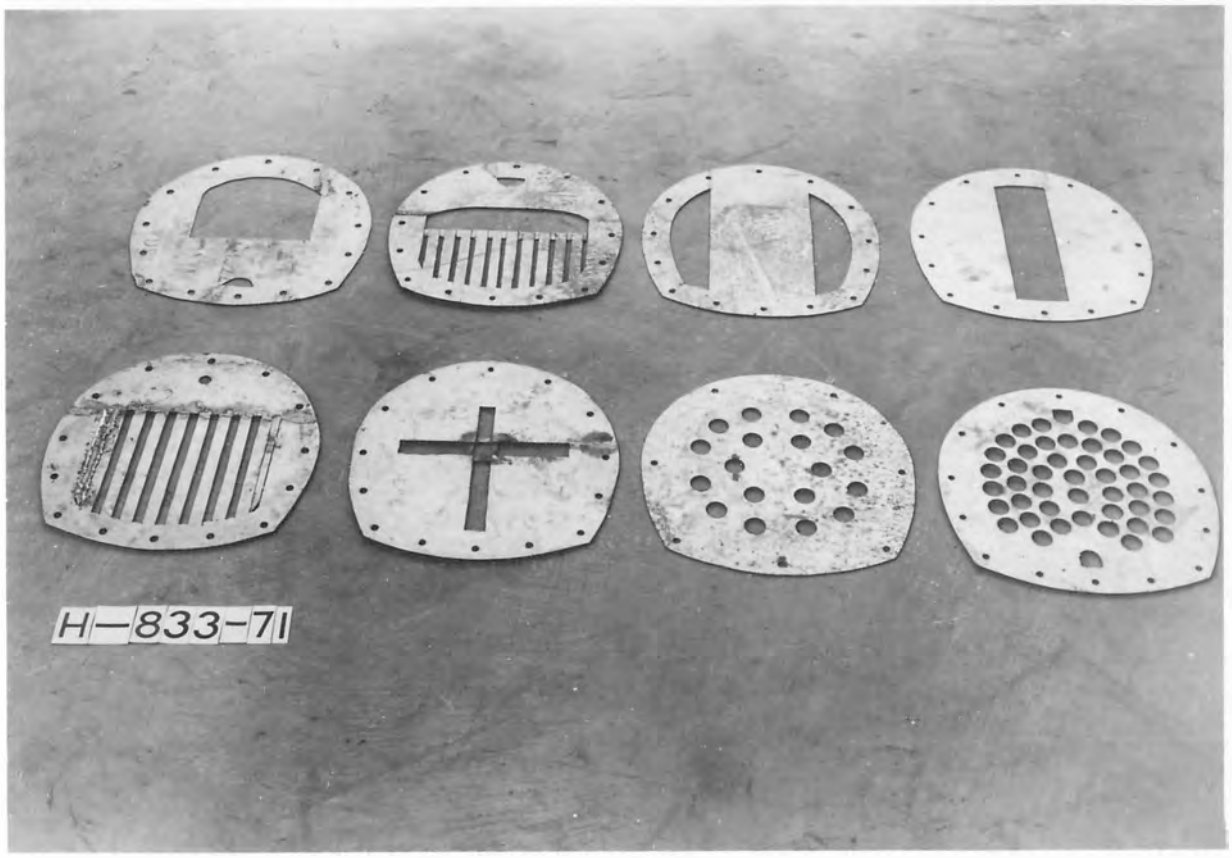


A. Basin length 32 feet; height from basin floor to tunnel invert, 9.6 feet

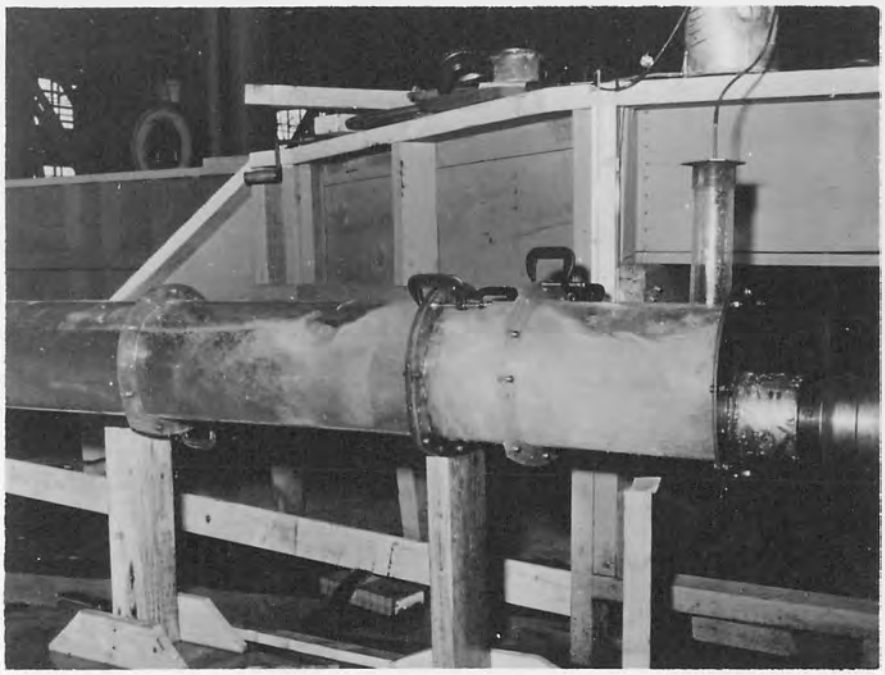


B. Basin length 76 feet; height from basin floor to tunnel invert, 14.5 feet

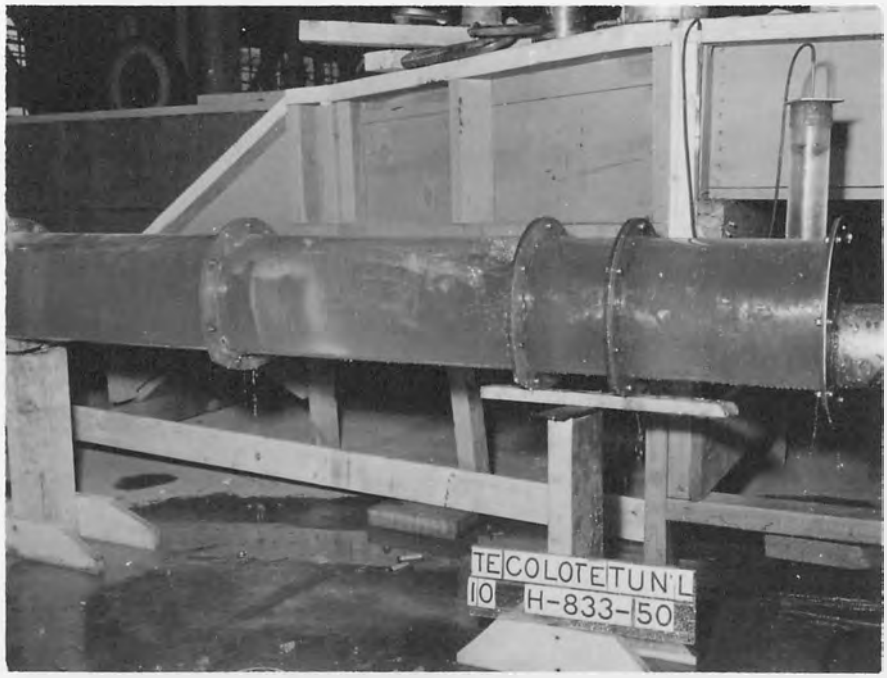
TECOLOTE TUNNEL
Operation of the 1:10 Scale Model of Stilling Basin Designs - without baffle piers - Flow of 100 cfs with 104 foot Head on Valve. Flow from Right to Left.



TECOLOTE TUNNEL
Representative Tunnel Baffles
1:10 Scale Model

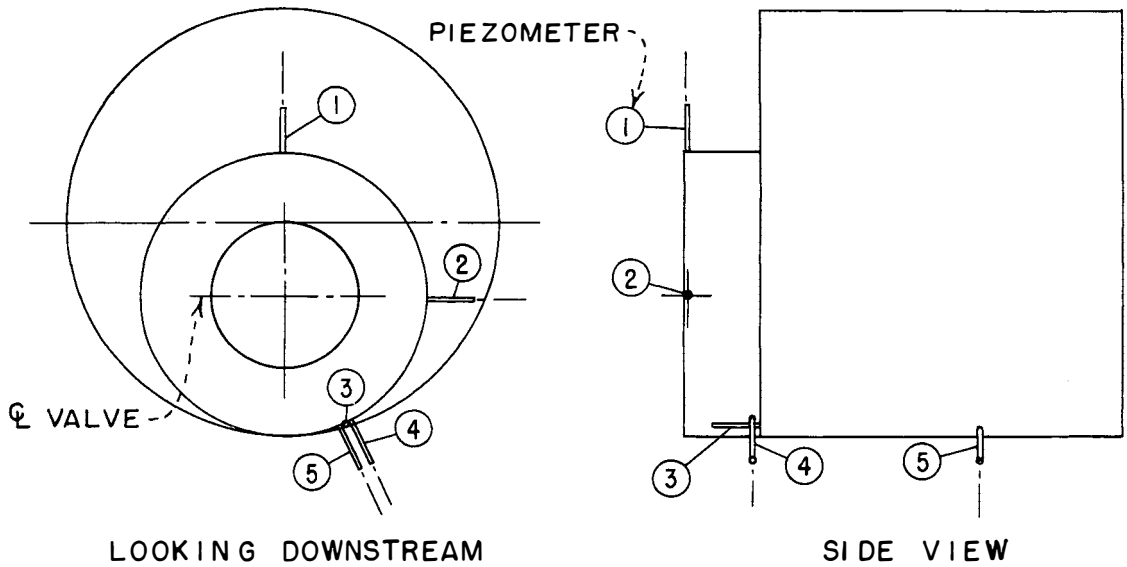


A. One tunnel baffle 15 feet from valve



B. Two tunnel baffles, 10 and 15 feet from valve. Note high water level in standpipe and the turbulence below the second baffle.

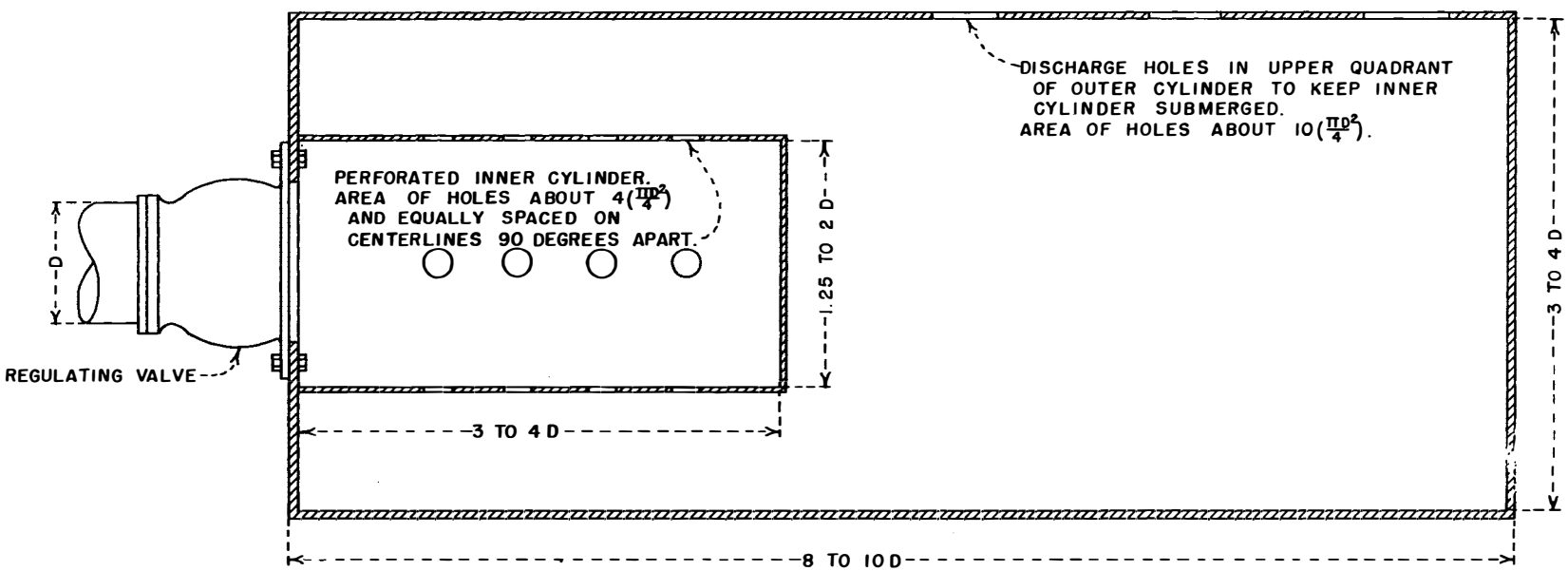
TECOLOTE TUNNEL
Operation of 1:10 Scale Model of Tunnel Baffle Designs with Flow of 100 cfs and 104 foot head on Valve.



FLOW GUIDE

WATER FLOWING AT 104 FEET HEAD			
PIEZOMETER	STATIC HEAD AT PIEZOMETER IN FEET OF WATER PROTOTYPE		
	100 CFS	50 CFS	25 CFS
1	8.5	4.5	1.25
2	6.5	3.0	1.75
3	13.5	7.5	5.0
4	7.0	4.5	3.5
5	15.0	11.0	7.0

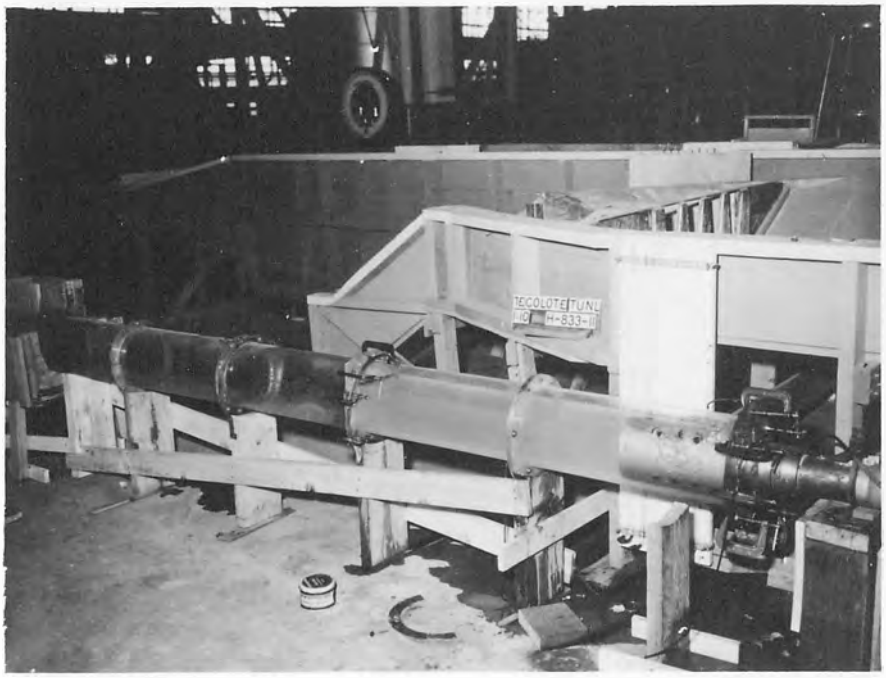
TECOLOTE TUNNEL
PRESSURES IN FLOW GUIDE
FINAL OUTLET DESIGN
1:10 SCALE MODEL



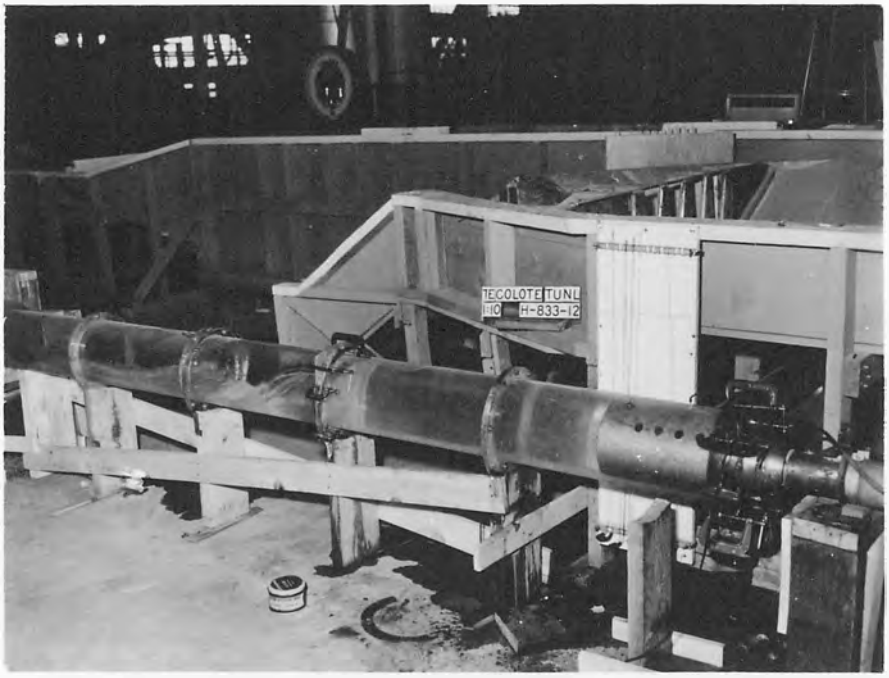
TECOLOTE TUNNEL

PROPOSED MUFFLER TYPE STILLING DEVICE

FIGURE 13
Report Hyd. 287



A. Flow 20 cfs. Head on valve, 11 feet



B. Flow 100 cfs. Head on valve, 104 feet

TECOLOTE TUNNEL
Operation of a 1:10 scale model of a muffler type stilling device.