UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MODEL STUDIES OF THE 20-FOOT OUTLET TUNNEL TO 15-FOOT PENSTOCK TRANSITION--DIVERSION SCHEME--ANDERSON RANCH DAM--BOISE PROJECT, IDAHO

Hydraulic Laboratory Report No. Hyd.-280

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

JUNE 21, 1950

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Research and Geology Division
Denver, Colorado
June 21, 1950

Laboratory Report No. 280
Hydraulic Laboratory
Compiled by: L. V. Wilson
Reviewed by: J. W. Ball
W. C. Case

Subject: Model studies of the 20-foot outlet tunnel to 15-foot penstock transition--Diversion scheme--Anderson Ranch Dam--Boise Project, Idaho.

PURPOSE OF STUDY

To develop a tunnel-to-penstock transition which will have satisfactory pressure characteristics when flowing full (normal condition) or partially full (diversion condition during construction).

CONCULSIONS

1. A permanent transition having satisfactory pressure characteristics with the transition flowing both full and partially full is shown in Figure 7.

a. The equation of the 30-foot transition profile is $Y = 0.16667X - 0.00278X^2$;

b. Representative pressures in the transition area are shown in Figures 5B and 5C. When the transition is flowing partially full and the water has a velocity of 80 feet per second, the lowest pressure as indicated by the model is 8 feet of water below atmospheric pressure.

2. The original transition design is unsatisfactory for diversion purposes because vapor pressure occurs on the floor and walls of the transition when it is flowing partially full (Figure 5A).

3. When water flows at high velocity through a transition section from a larger to a smaller pipe, the reduction in pipe diameter must be more gradual when the transition is to flow partially full than when the transition is to always flow full; otherwise cavitation pitting may be encountered.

RECOMMENDATIONS

1. Incorporate the transition shown in Figure 7 in the Anderson Ranch Tunnel for both the construction diversion scheme and the final structure.

INTRODUCTION

Anderson Ranch Dam is located on the South Fork of the Boise River about 45 miles southeast of Boise, Idaho (Figure 1). The outlet works consist of a trashrack, inlet structure, bulkhead gate, a 20-foot-diameter concrete-lined diversion tunnel, a 15-foot diameter plate-steel penstock, and five 72-inch hollow-jet valves. The penstock extends from a concrete tunnel plug within the dam to the powerhouse and outlet structure (Figures 2 and 3). During construction of the dam, the outlet tunnel will be used for diversion of the river water through a temporary channel extending from the outlet portal of the tunnel to the river channel. At low river stages, during construction, the tunnel will flow only partially full. However, during this period the releases will be regulated by the coaster gate at the tunnel entrance and the velocity will be in excess of 80 feet per second, so subatmospheric pressures are expected in the transition area. The study reported herein was made to verify the presence of subatmospheric pressures and to derive a method of eliminating them or reducing them to noncritical values.

Liaison was maintained between the Hydraulic Laboratory and the Outlet Works Section of the Dams Division during the model testing.

THE INVESTIGATION

The principal objective of the study was to investigate the pressure distribution in the transition area when it flowed partially full; that is, with a free water surface. This condition exists when water in the 20-foot tunnel is flowing 5 feet deep at a velocity of 80 feet per second (maximum expected diversion discharge).

The Model

The development of a satisfactory transition was accomplished by using a 1:40 scale model. In the flow direction, the model consisted of a 20-foot run of 6-inch standard pipe representing the 20-foot-diameter tunnel, an interchangeable short section of 6-inch transparent plastic pipe for closed-conduit and open-channel flow studies, a transition section, and a short section of 4-1/2-inch plastic pipe to represent the 15-foot-diameter penstock. Water was supplied to the model by a centrifugal pump, and the flow was measured by a 4-inch venturi meter. Pressures on the wall surface of the transition test sections were measured with piezometers (Figure 4). The depth of water for open-channel flow was controlled by an orifice, shaped like a segment of a circle, which was placed

upstream from the transition. The arc of the orifice coincided with the bottom of the tunnel. A 6-inch long metal lip, normal to the plate and flush with the horizontal chord of the orifice, was extended upstream to suppress the top of the opening and form a high-velocity stream representing the prototype open-channel flow conditions. The average velocity for the partially filled transition was obtained by dividing the quantity of water flowing through the orifice by the orifice area. For closed conduit flow with the orifice plate removed, the average velocity was obtained by dividing the quantity of water passing through the system by the area of the 20-foot-diameter tunnel. Piezometer head measurements and visual observations were used to determine what modifications were to be made to the original design.

Elliptical Transition

The original design was a 10-foot long transition having an elliptical profile of $Y^2 = 6.25 - 0.625X^2$ (Figure 4A). The model section was constructed of sheet metal and the transition formed of beeswax. This shape (Figure 5D) was tested with closed-conduit flow and found to be satisfactory. When tested with open-channel flow, the transition was found to be too abrupt with a tendency for separation of flow from the walls and floor just downstream from the converging section (Figures 5A and 6A). This resulted in vapor pressure at 90-foot-per-second velocity and within a foot of vapor pressure at 75-foot-per-second velocity (Figure 5A). The presence of these severe subatmospheric pressures made it necessary to modify the transition.

Conical Transitions

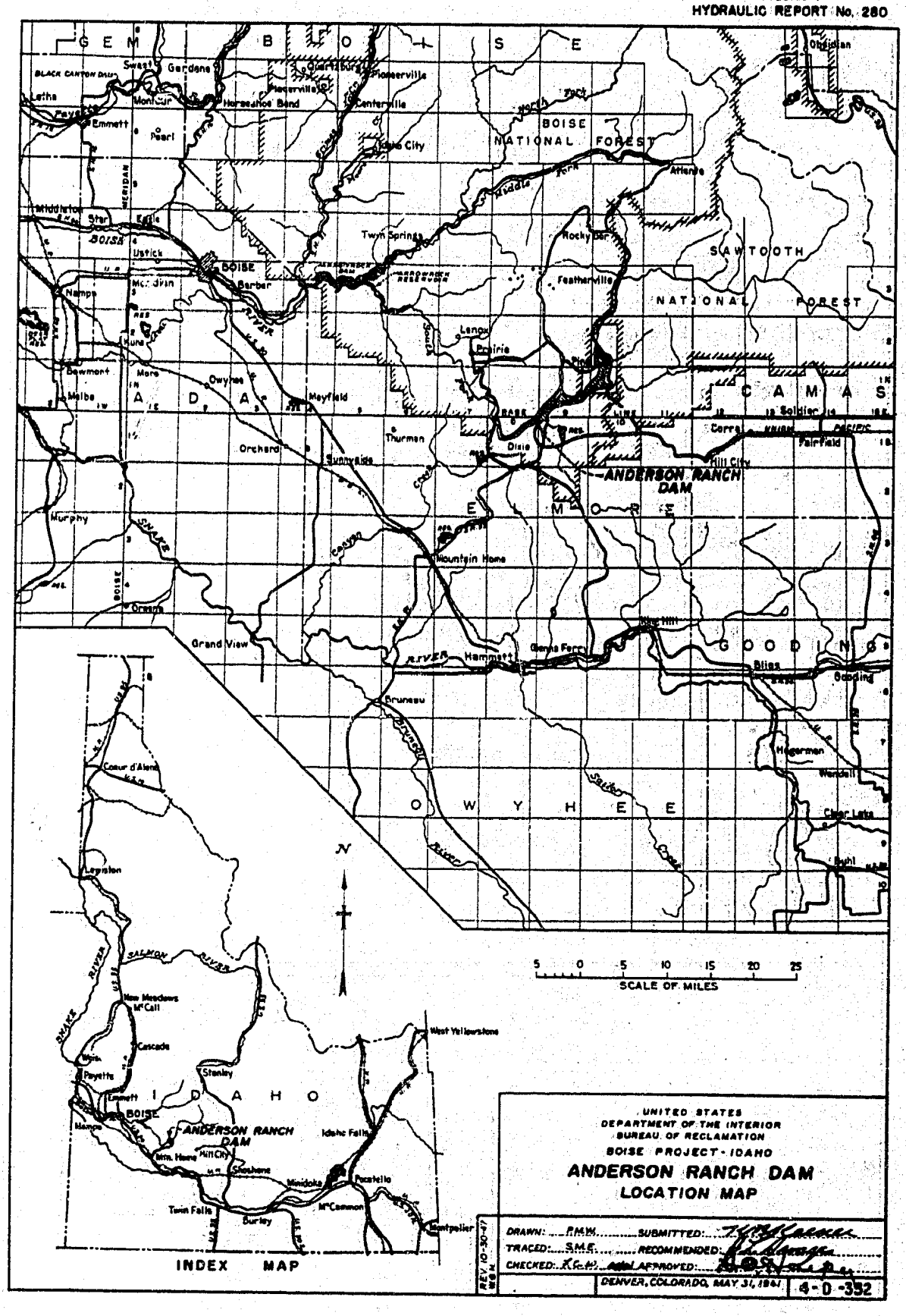
Since the original transition was only 10 feet in length, it was stipulated that all modifications should be limited to this length or less. It was believed that about a 5-foot temporary conical transition could be used to increase the pressure during diversion, and after completion of the dam, the conical transition could be removed and the permanent transition installed. The first conical section tested had a 20-foot-diameter inlet tapering to a 15-foot-diameter outlet in an over-all length of 5 feet. This increased the pressure slightly. The conical section lengths were increased until the allotted 10-foot length was utilized. This length gave fair results, but using a 10-foot temporary transition was found to be impractical economically. The cost of construction, installation, and removal of the conical section, plus the installation cost of the final transition would cost more than the installation of a longer permanent transition section.

Parabolic Transition

A transparent plastic transition, having a parabolic profile of $Y = 0.1605X - 0.00258X^2$ and 31 feet long prototype (Figure 4B), was tested for closed-conduit flow (Figure 5C) and for open-channel flow (Figures 5B and 6B). Undesirable subatmospheric pressures occurred at 100-foot-per-second velocity with open-channel flow, but at the normal velocity of 80 feet per second pressures were high enough to preclude cavitation conditions.

Flow was much smoother at partial flow than in the conical and elliptical transitions. This transition was shortened to 30 feet with a profile equation of $Y = 0.16667X - 0.00278X^2$ for the final design transition (Figure 7). This change was so small that it was not considered necessary to build and test a model section of this design.

FIGURE 1
HYDRAULIC REPORT No. 280



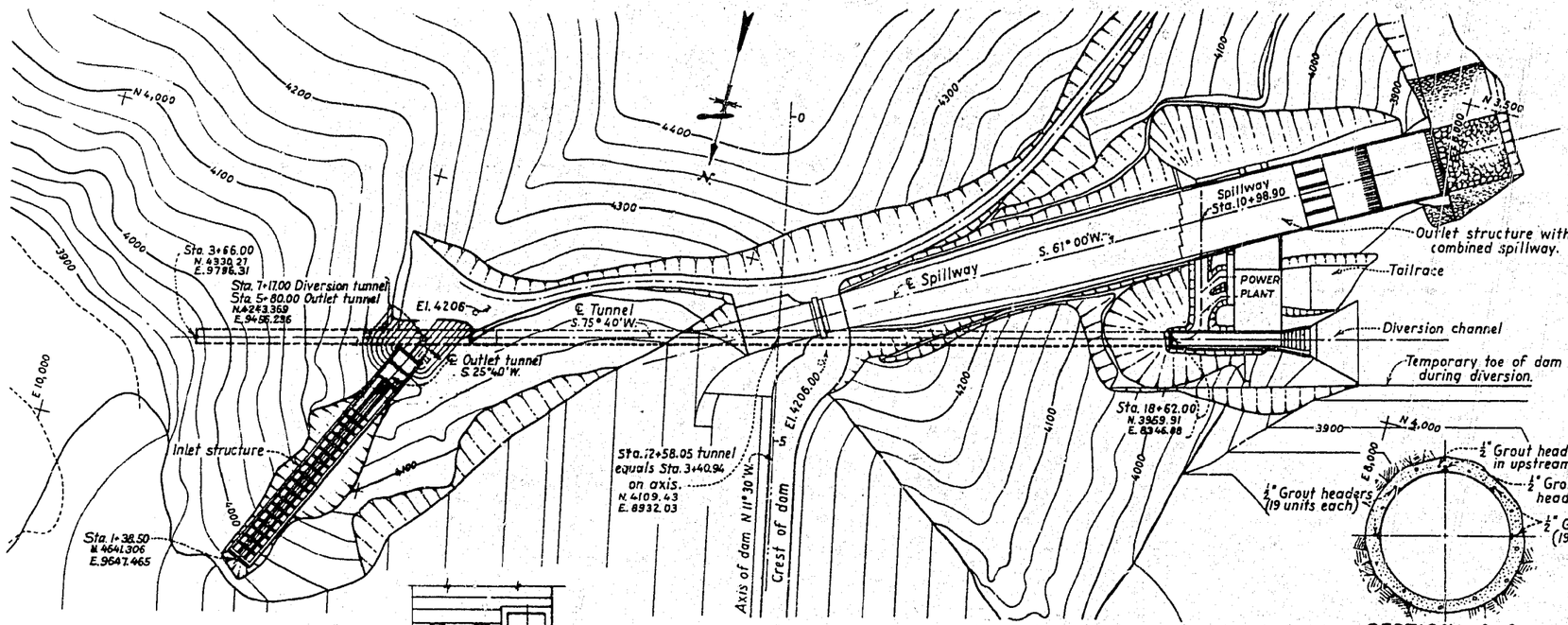
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO

ANDERSON RANCH DAM
LOCATION MAP

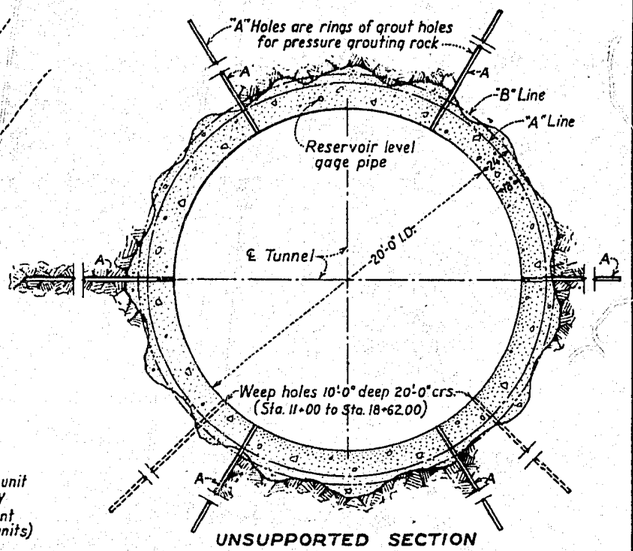
DRAWN: P.M.W. SUBMITTED:
TRACED: S.M.E. RECOMMENDED:
CHECKED: K.C.H. Acting APPROVED:

DENVER, COLORADO, MAY 31, 1961

4-D-332

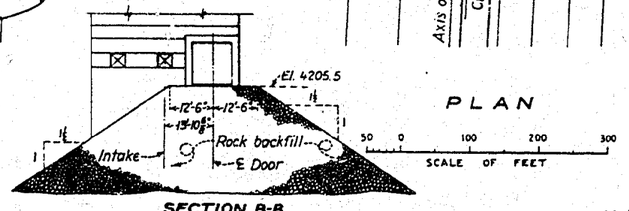


SECTION A-A



UNSUPPORTED SECTION

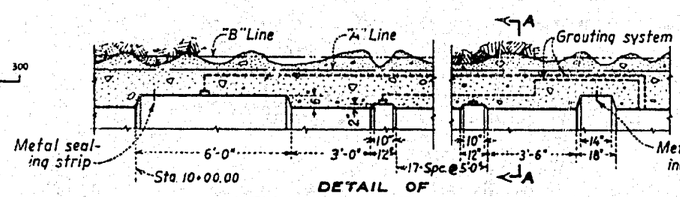
SCALE OF FEET



PLAN

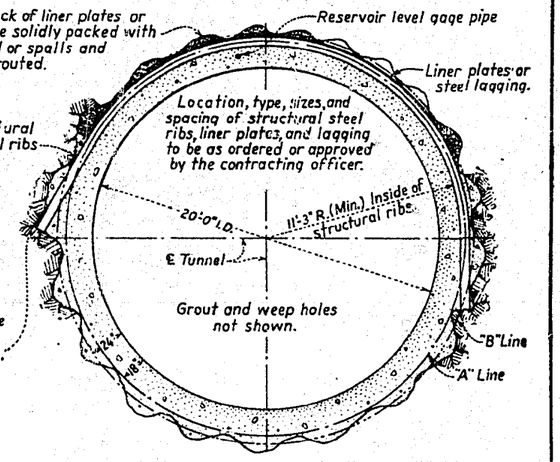
SCALE OF FEET

SECTION B-B



DETAIL OF KEYWAYS AT TUNNEL PLUG

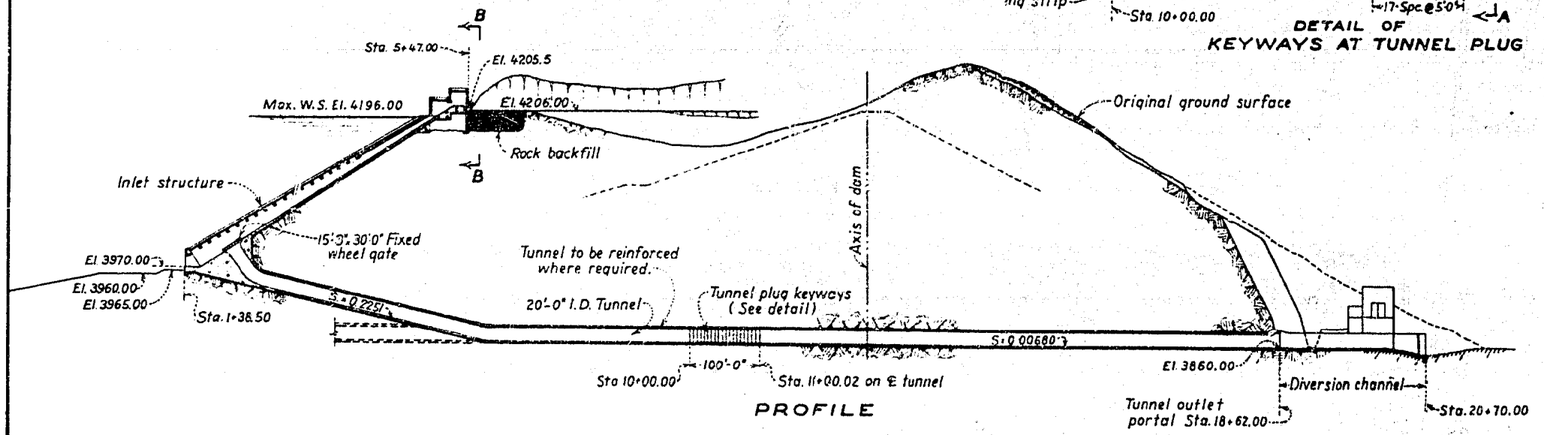
All spaces back of liner plates or lagging to be solidly packed with clean gravel or spalls and pressure grouted.



Excavation and concrete outside of "B" line, required for supports, included in cost of installing supports.

SUPPORTED SECTION

TYPICAL TUNNEL SECTIONS



PROFILE

NOTE

Construction after end of river diversion thru tunnel is not shown on this drawing.

REFERENCE DRAWINGS

INLET SHAFT AND DIVERSION TUNNEL PLUG	4-D-379
TUNNEL OUTLET PORTAL	4-D-380
DIVERSION CHANNEL	4-D-381
RESERVOIR LEVEL GAGE PIPING	4-D-375
GROUT OUTLET INSTALLATION	40-D-2733

REV. 4-26-45
REV. 12-26-42
REV. 4-30-42
REV. 3-15-43

UNITED STATES
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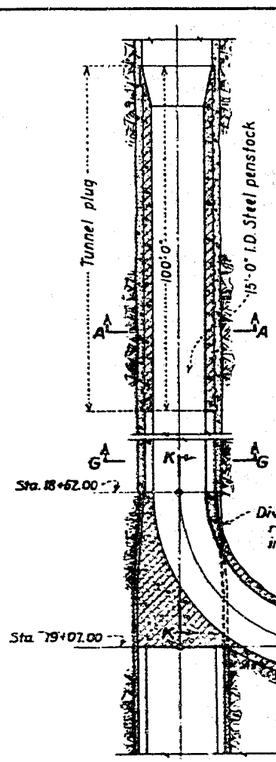
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO

ANDERSON RANCH DAM
OUTLET WORKS
ALINEMENT PROFILE AND SECTIONS
FIRST STAGE CONSTRUCTION

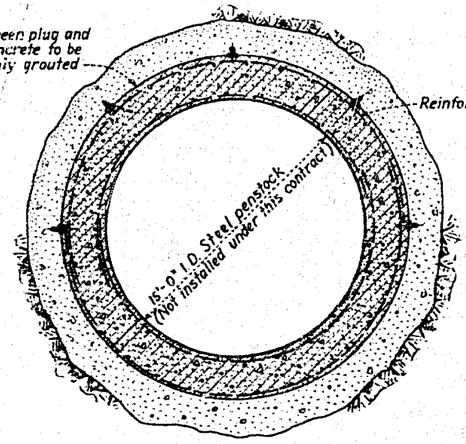
DRAWN: J.E.S. SUBMITTED:
TRACED: R.E.D. RECOMMENDED:
CHECKED: G.N. C.C.C. APPROVED:

DENVER, COLORADO, MAY 31, 1941

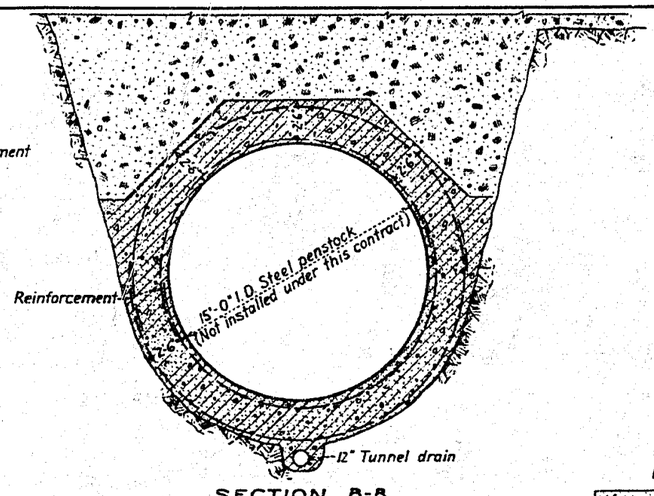
4-D-345



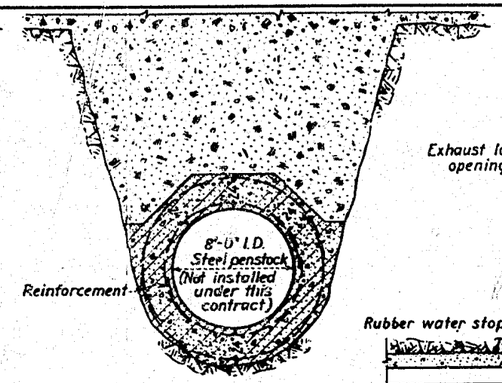
SECTIONAL PLAN ALONG ℄ PENSTOCKS



SECTION A-A



SECTION B-B



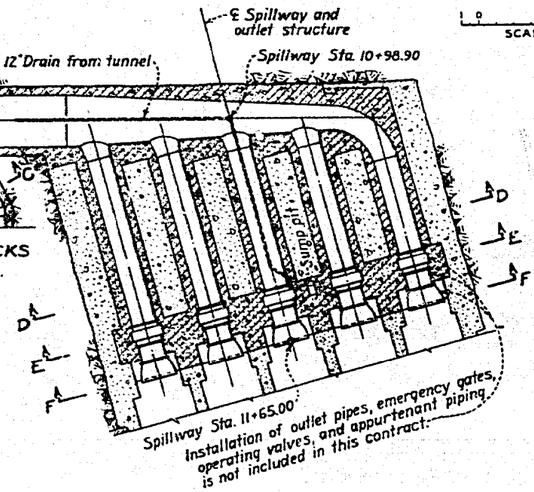
SECTION C-C

EXPLANATION

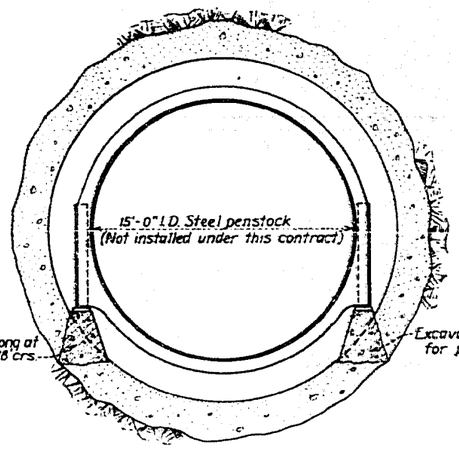
First stage concrete

Second stage concrete

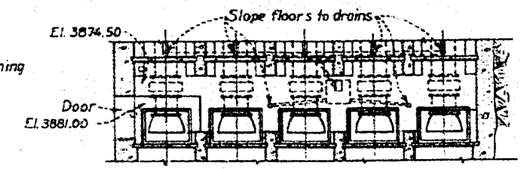
10 0 5 10
SCALE OF FEET



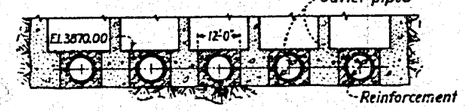
10 0 10 20 30 40 50
SCALE OF FEET



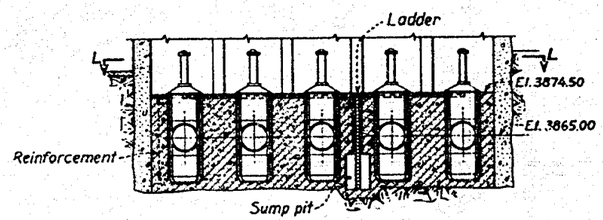
SECTION G-G



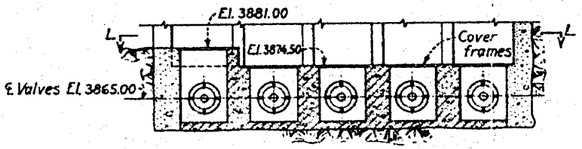
SECTION L-L



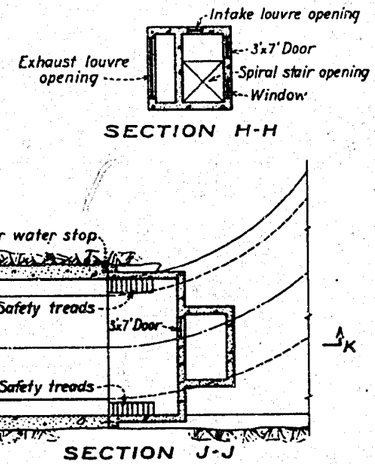
SECTION D-D



SECTION E-E

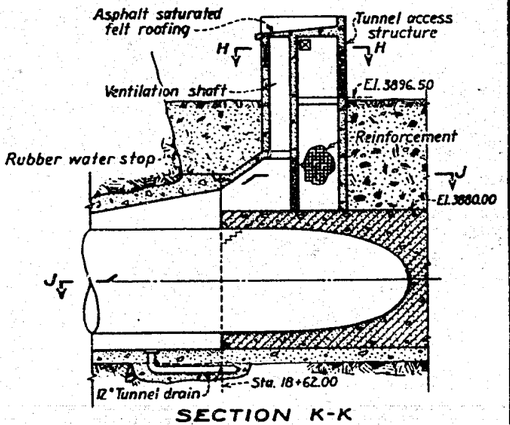


SECTION F-F



SECTION H-H

SECTION J-J



SECTION K-K

5 0 10 20 30
SCALE OF FEET

NOTE

Reinforcement shown is for purposes of illustration only. The entire structure is to be adequately reinforced.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO

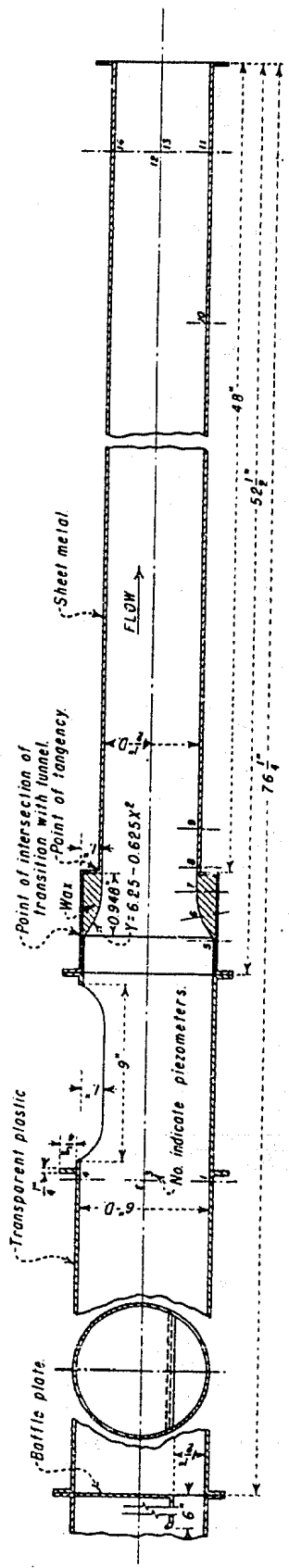
ANDERSON RANCH DAM
OUTLET WORKS
SECOND STAGE CONSTRUCTION

DRAWN J.E.S. SUBMITTED
TRACED C.W.C.-H.A.S. RECOMMENDED
CHECKED G.E.S.-A.J.T. APPROVED

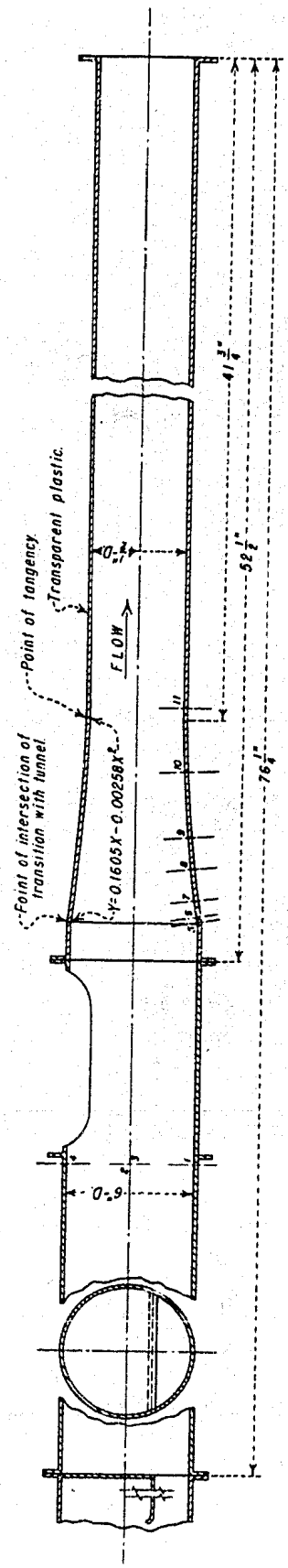
DENVER, COLORADO MAY 21, 1941

4-D-349

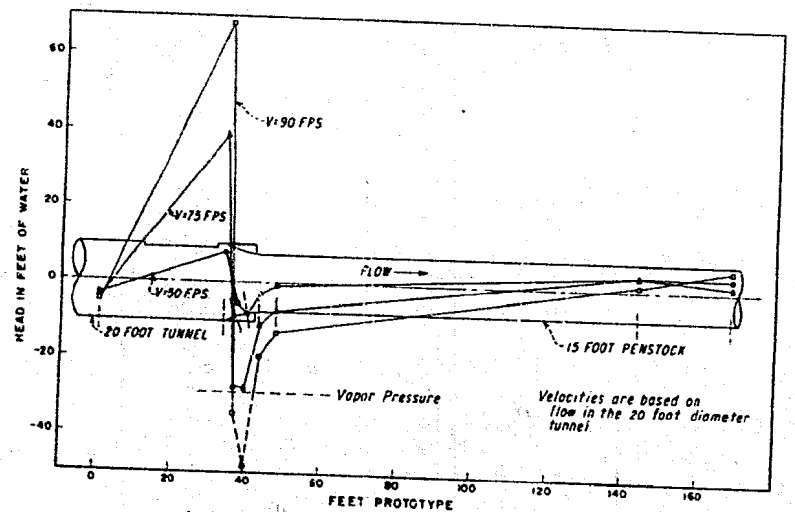
BOISE PROJECT - IDAHO
ANDERSON RANCH DAM
OUTLET WORKS TRANSITION
MODEL SCALE 1:40
MODEL DETAILS



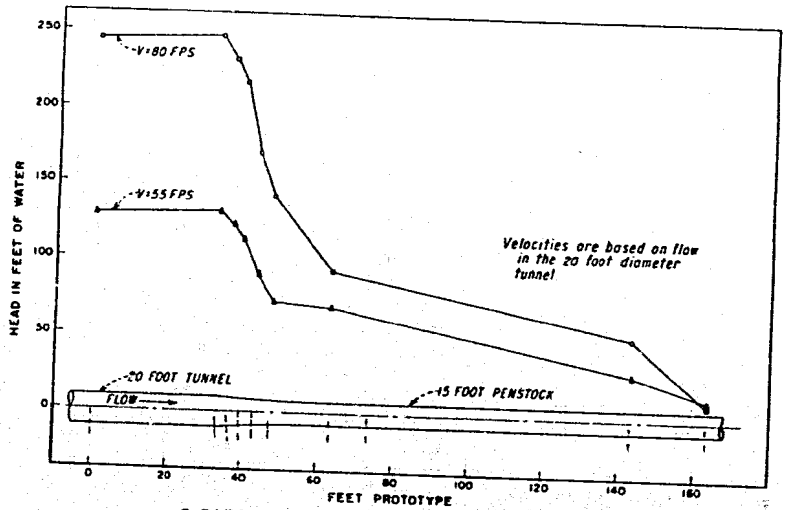
A. ELLIPTICAL TRANSITION



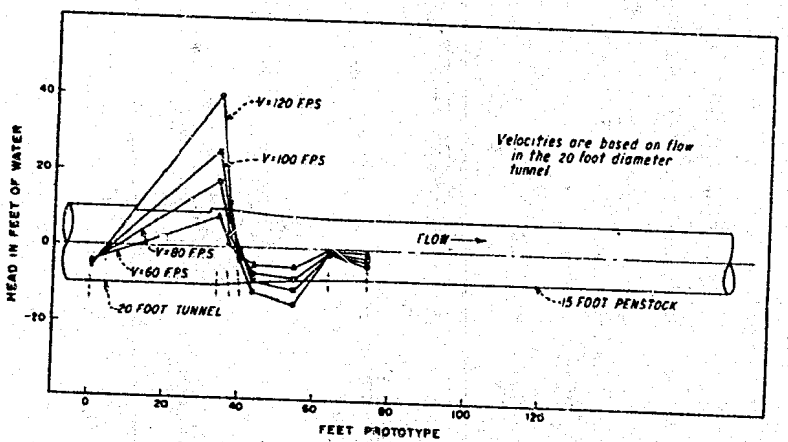
B. PARABOLIC TRANSITION



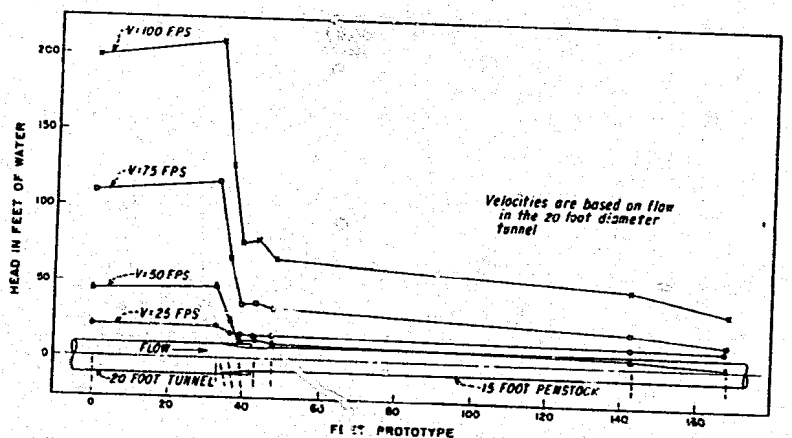
A. ELLIPTICAL TRANSITION – OPEN CHANNEL FLOW



C. PARABOLIC TRANSITION – CLOSED CONDUIT FLOW



B. PARABOLIC TRANSITION – OPEN CHANNEL FLOW



D. ELLIPTICAL TRANSITION – CLOSED CONDUIT FLOW

BOISE PROJECT - IDAHO

ANDERSON RANCH DAM

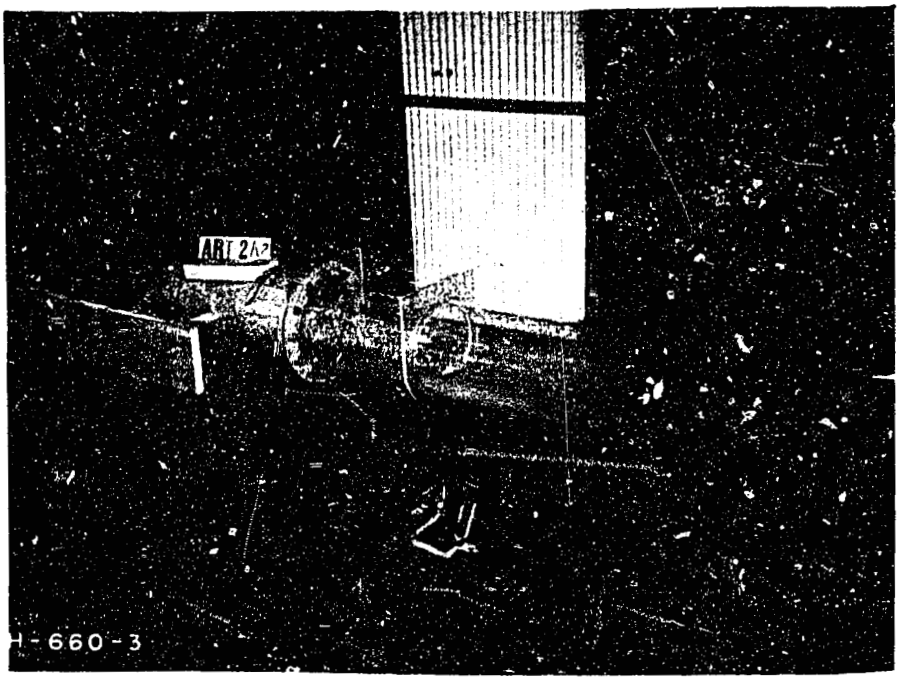
OUTLET WORKS TRANSITION

MODEL SCALE 1:40

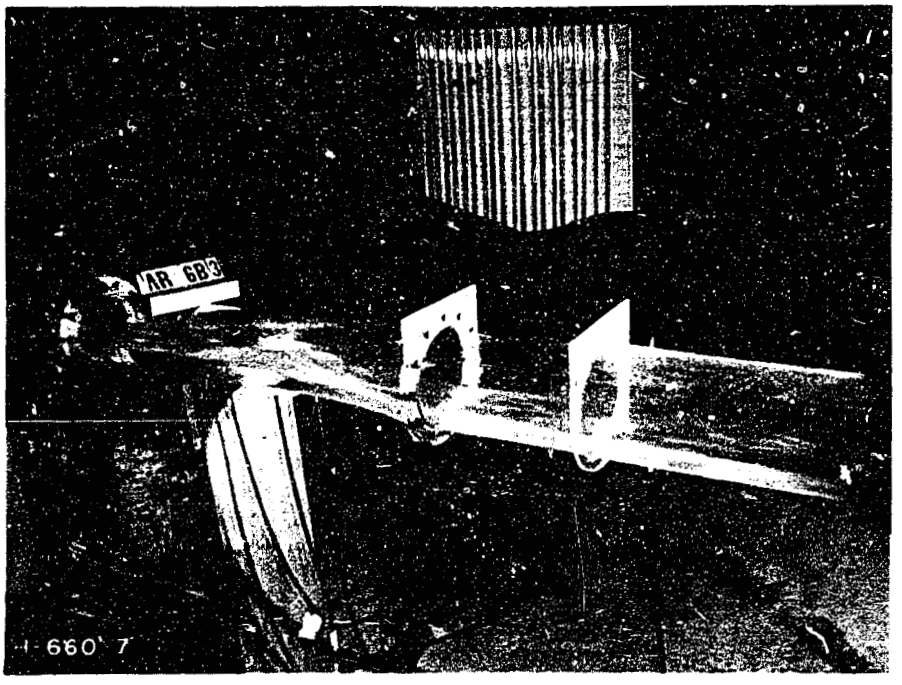
PRESSURE DISTRIBUTION CURVES

FIGURE 5

HYDRAULIC REPORT No. 280

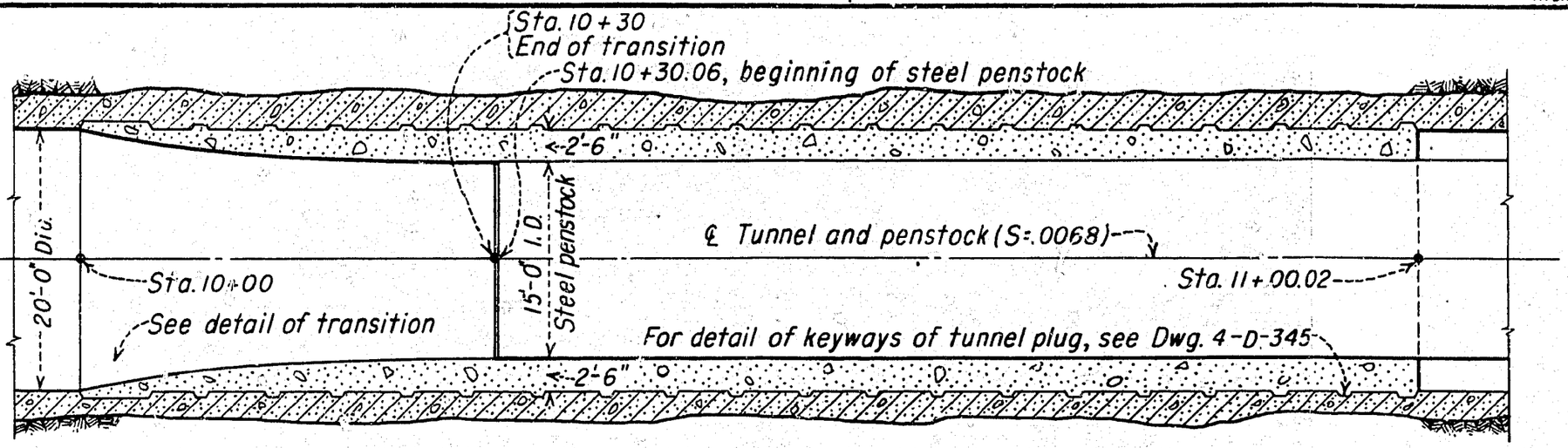


A. Elliptical Transition-open flow from right to left, velocity of 75 fps.



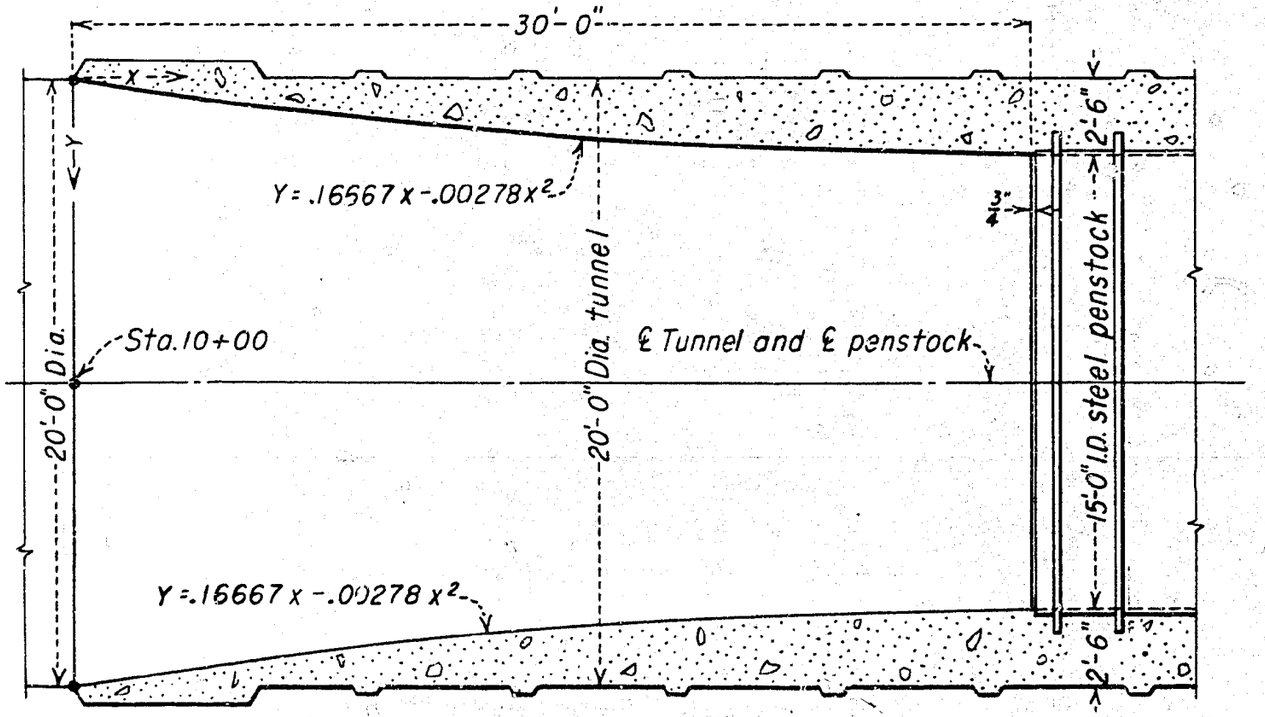
B. Parabolic Transition-open flow from right to left, velocity of 80 fps.

TRANSITION FLOW PHOTOGRAPHS
Anderson Ranch Dam
Model Scale 1:40



SECTIONAL ELEVATION ON ℄ TUNNEL

5 0 5 10 15
SCALE OF FEET



DETAIL OF TRANSITION

1 0 5 10
SCALE OF FEET

REFERENCE DRAWINGS

GENERAL PLAN AND LAYOUT	4-D-901
ALINEMENT PROFILE AND SECTIONS- FIRST STAGE CONSTRUCTION	4-D-345
PENSTOCK AND OUTLET PIPES- TUNNEL PORTION	4-D-545
INLET STRUCTURE-TUNNEL PLUG- REINFORCEMENT	4-D-1225

REV. 10-27-47 W.E. CAW
11-12-47 H.E.N. CAW

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT — IDAHO

ANDERSON RANCH DAM
OUTLET WORKS—INLET STRUCTURE TUNNEL PLUG

DRAWN C.A.S. SUBMITTED W. G. Hale
TRACED V.M.M. RECOMMENDED John A. Bard
CHECKED CAW APPROVED J. C. Keener
ACT. ASST. CHIEF ENGINEER

DENVER, COLO. OCT. 3, 1947

4-D-1177