UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE 7-FOOT 6-INCH BY 9-FOOT 0-INCH PALISADES REGULATING SLIDE GATE PALISADES PROJECT, IDAHO

Hydraulic Laboratory Report No. Hyd-387

ENGINEERING LABORATORIES

OFFICE OF THE ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

June 21, 1954

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Office of the Assistant Commissioner
and Chief Engineer
Engineering Laboratories
Denver, Colorado
June 21, 1954

Laboratory Report No. Hyd-387
Hydraulic Laboratory
Written by: W. P. Simmons, Jr.
Reviewed and
checked by: J. W. Ball

Subject: Hydraulic model studies of the 7-foot 6-inch by 9-foot 0-inch Palisades regulating slide gate--Palisades Project, Idaho

PURPOSE

To develop a large, high-capacity gate for free discharge regulation into an open stilling basin at heads up to 240 feet.

CONCLUSIONS

1. A downstream-seal slide gate with narrow, specially designed gate slots and a leaf with a 45-degree sloped bottom with the spring point as far downstream as practicable will produce smooth, relatively spray-free flow onto a stilling basin apron (Figures 16, 27, and 28). Pressure measurements on the 1:19 model of the recommended gate design without vents indicate that it will be cavitation-free at all openings, except those between 97 and 100 percent. Venting will be required at openings between 97 and 100 percent. Upon reaching the full-open position, the gate is again cavitation-free without venting.

2. Air vents in a band across the roof of the downstream frame near the gate leaf will limit the negative pressures at 97 to 100 percent openings to safe values (Figure 21).

3. Narrow gate slots produce a smoother stream with less spray and smaller sidewall fins than wide slots. The gate leaf may need to be thick across the flow passage to resist bending, but its thickness should be reduced at the sidewalls to the much smaller dimensions required for the shear loads to permit the use of narrower slots (Figure 17).

4. By outwardly offsetting the downstream slot corners 1/2 inch (prototype), and then slightly converging the walls to return the passage width to that of the upstream frame, serious negative pressures are avoided at the slots and on the side walls and roof of the downstream frame (Figure 21).

5. The coefficient of discharge for the fully opened 7-foot 6-inch by 9-foot 0-inch recommended slide gate is about 0.94 based upon the area of, and the total head in, the 114-inch conduit (Figure 20).

6. The recommended gate design may be used without change for discharge into closed or open conduit, as well as onto a stilling basin apron (Figures 14, 15, and 16). As with any control device, venting will be required where the discharge enters a closed conduit.

7. The recommended gate design may also be used for submerged installations. Care must be taken to insure that adequate submergence is provided for the head differential available. Data is presented which makes a determination of this required submergence possible (Figures 24 and 25).

8. The necessary test facilities should be provided at Palisades Dam so that observations can be made during the operation of a full-sized gate.

9. An upstream seal gate with wide gate slots and without a controlled flow contraction prior to the release of the water is not suitable for free discharge regulation into an open stilling basin.

10. Deflectors which provide sufficient flow contractions for good gate operation reduce the flow capacity of a given size gate. The jet flow valve (fixed wheel gate) developed for Shasta Dam (Report No. Hyd-201) is an upstream seal gate with the contraction produced by a 45-degree inwardly sloping circular orifice immediately upstream from the fixed wheel leaf. This design has been found excellent in field service and has a discharge coefficient of 0.70 based upon total head and conduit area. The model studies reported here indicate that no particular improvement can be made on this type gate.

11. Devices such as honeycomb-like baffles and guide vanes placed immediately upstream from the gate are generally impracticable. Similarly, extensions to the leaf to provide controlled contractions are impracticable.

ACKNOWLEDGMENT

The gate testing and development program described in this report was the result of cooperative efforts of the Dams Branch, the Mechanical Branch, and the Engineering Laboratories.

INTRODUCTION

Palisades Dam is located in Idaho on the south fork of the Snake River approximately 8 miles west of the Idaho-Wyoming border and about 75 air-line miles northeast of Pocatello (Figure 1). The

dam rises about 260 feet above the river bed and is a rock-faced, compacted earth structure 2,200 feet long at the crest (Figure 2). It will provide water storage for supplementary irrigation to 650,000 acres now receiving water from the Snake River and from its tributaries above Milner Dam. It will provide direct flood protection for 100,000 acres of agricultural land upstream from Idaho Falls, and indirect protection to the communities and lands farther downstream. Its powerplant will develop a yearly average of 387 million kilowatt hours of electricity.

A spillway, controlled by two 20- by 50-foot radial gates, is located at the left abutment of the dam (Figure 2). The water released by the spillway, up to a maximum flood flow of 48,000 cfs, is discharged through a 28-foot-diameter tunnel to the river channel downstream from the dam. The outlet works are also located at the left abutment and release flows up to 42,000 cfs through six 7-foot 6-inch by 9-foot 0-inch regulating slide gates and two 96-inch hollow-jet valves (Figure 3). Two of these slide gates are connected to the 26-foot-diameter penstock which serves the generator units in the powerhouse. The other four slide gates and two hollow-jet valves are connected to a second 26-foot-diameter conduit. Normal water releases, in excess of the turbine requirements, will be made through the hollow-jet valves. Larger releases, including floodwaters, will be made through the slide gates. The maximum head on the outlet works is 235 feet.

The desirability of using a minimum number of outlet branches and control structures to handle the flows through the dam requires that large quantities of water pass through each branch. The discharge coefficient of approximately 0.70 for hollow-jet valves (based on conduit area and total head) was not high enough to permit discharging the required amount of water without an excessive number of valves, or valves of excessive proportions. On the other hand, the favorable discharge coefficient of more than 0.90 for slide gates permits passing the 42,000 cfs of water through only seven gates 7 feet 6 inches wide by about 9 feet 0 inches high. One of these gates was replaced with two 96-inch hollow-jet valves in the final outlet works arrangement making a total of six slide gates and two hollow-jet valves (Figure 3).

The 235-foot head under which the outlet gates will operate is much greater than the heads at which large regulating slide gates have previously been used. It was therefore necessary to develop a gate design suitable for use at any opening and any head up to the above maximum. This slide gate development program and the results obtained from it are described in this report.

INVESTIGATION

Upstream Seal Gate

The Design

A tight-sealing, easy-moving gate with a minimum hydraulic downpull was desired. These conditions seemed best filled by a fixed wheel gate with the skin plate and seal on the upstream face of the leaf. A tentative design embodying these features was prepared by the designers (Figure 4). The gate frame downstream from the leaf was made wider than the 8-foot 0-inch-wide upstream frame to remove the downstream slot corner from the path of the water. Similarly, the roof of the downstream frame was higher than the roof of the 9-foot 6-inch-high upstream frame. The gate slot was wide to accomodate the thick gate leaf and its wheels.

Model Description

A 1:19 scale model was built of a 7-foot 6-inch by 9-foot 6-inch gate (Figure 5). This gate was 6 inches narrower than the one originally proposed and was used because its full-open area of 71.2 square feet approximately equaled the 71.0-square-foot area of the 114-inch conduit. Transparent plastic side plates were used to form the outside boundaries of the gate slots so the flow inside the slots could be observed. The gate was connected to a 6-inch inside diameter, smooth-walled brass pipe by a transition. The 6-inch pipe, at the model scale of 1:19, represented the prototype 114-inch steel conduit, and the 13-foot-long model section was connected to a 4-foot-diameter pressure tank by a bellmouth. Water was supplied to the tank through the central laboratory piping system which included Venturi meters for measuring the rate of flow. A ring of four piezometers was provided 1 diameter upstream from the outlet of the 6-inch pipe to measure the piezometric head of the water entering the gate-transition assembly. The water discharged freely into the atmosphere after leaving the gate and returned to the laboratory supply reservoir for recirculation.

Model Tests

Tests on preliminary design. At the full-open position, water flowed smoothly out of the gate without touching the sides or top of the downstream frame (Figure 6A). However, when the gate was closed so that the leaf entered the stream, the flow at the top of the gate opening spread and struck the slot corners. As the gate was closed further, more of the stream entered the slot. At a closure of 3 percent (97 percent opening) the model slots were filled from the floor to the top of the bonnet. At 83 percent opening, large quantities of spray occurred at the corners formed by the gate leaf and the side walls (Figure 6B). At smaller openings, pressure built up within the slots and forced water out of the bonnet and down the back of the leaf. This water fell on the issuing jet to cause additional spray (Figures 6C and D).

Effect of widening downstream frame. It was evident that the downstream gate frame was not wide enough to clear the flow when the leaf extended into the stream. To determine how wide the frame should be, the frame was removed, and the leaf was held in place with clamps (Figures 7A and B). Water was passed through the gate, and the angle of flow divergence noted. This divergence was much greater than anticipated, particularly at the small openings, and it was impracticable to provide a downstream frame wide enough so the corners would not be struck by the water.

Effect of gate leaf extensions. It was noted that the water which entered the slots came primarily from the top of the jet at the sides of the gate. If this water could be directed straight downstream from the leaf, rather than being allowed a sideward component, there would be no impingement on the slot corners and the flow would be smoother. Various shaped extensions were added to the bottom corners of the leaf, and an extension was added to the center of the leaf in attempts to produce the desired flow (Figures 8A, B and C). None of the extensions were found effective.

An extension which projected upstream the equivalent of 10 inches from the leaf face (Figure 8D), and thereby shifted the point of control 10 inches upstream from the slot, improved the flow conditions. A longer extension would probably have produced even better flow conditions, but short tube action under the gate at small openings with either the 10-inch or the longer extension would introduce severe negative pressures and cavitation. The tests were discontinued because of the pressure and structural problems.

Effect of baffles upstream of gate. It appeared that if the flow at the gate leaf were constrained to move parallel to the floor and walls of the frame there would be less flow contraction under the leaf and less tendency for the stream to spread into the slots. A honeycomb-like baffle (Figure 9A) immediately upstream from the leaf improved the flow near the slots. A second honeycomb, with passages which converged from the sides toward the center and from the roof toward the floor, was also used (Figure 9B), but the action was too severe and the water formed a high vertical fin at the top of the stream. In addition, head losses were high. With both honeycombs there was a shift in control from the gate leaf to the upstream edge of the honeycomb when the leaf bottom was level with, or slightly below, a horizontal honeycomb member. This control shift was objectionable and steps were taken to relieve it by removing the central portion of the grid so that only a strip remained on each side of the passage (Figures 9C and D). The control shift was greatly reduced from that with the full grids, and less water entered the slots than would have entered if the strips were not in place. Nevertheless there was considerable turbulence at the slots and large fins formed on the sides of the jet. It appeared that for the Palisades installation the objectionable features of the honeycombs outweighed the desirable features, and the tests were terminated.

Effect of flow deflectors. Previous experience with the jet flow valve (fixed wheel gate, Report No. Hyd-201) indicated that, by deflecting the flow toward the gate center line immediately upstream from the gate leaf, the flow could be made to clear the slot corners downstream. Several deflector designs were used on the walls, floor, and ceiling of the Palisades gate model, and the operation with the equivalent of 2-inch, 90-degree side wall deflectors and a 6-inch, 90-degree floor deflector is shown in Figure 10. At the full-open position the side contraction, without a corresponding ceiling contraction, produced a fin at the top of the stream that rose higher than the gate bonnet (Figure 10A). Closing the gate 3 percent eliminated this fin (Figure 10B). In general, the flow characteristics were good. However, the coefficient of discharge of the full-open gate, based upon the cross-sectional area of the conduit 1 diameter upstream from the transition section and upon the total head at this point, was 0.71. At the 3-percent closed position the coefficient was 0.67. These values were much lower than had originally been sought.

The design of the gate at this point resembled that of the jet flow valve (fixed wheel gate), with the exception that the orifice was rectangular instead of round. It was felt that not enough advantage could be gained over the jet flow valve to warrant further study at this time. The investigation was therefore shifted to study the possibilities of developing a downstream seal gate suitable for the high heads and flows at Palisades Dam.

Downstream Seal Gate

The Design

The customary "standard, high-pressure slide gate," which is a downstream seal gate, has hydraulic deficiencies which greatly reduce its usefulness and dependability. Cavitation in serious proportions has been encountered on the gate leaves, and on the gate frames near the slots. Some of the cavitation damage at Caballo Dam (maximum head 75.25 feet) is shown in Figure 11. At Rye Patch Dam (maximum head 53.35 feet) the bottom of the gate leaves were so badly eroded that large areas were eaten through the castings (Figure 12). During model tests on Cedar Bluff and Medicine Creek outlet works the jet from the standard gate was found to be so poorly distributed that the stilling basins immediately downstream could not operate properly. It became necessary to redesign the gate leaves and slots during the model tests to obtain the required smooth stream (Reports No. Hyd-245 and Hyd-273). Conditions such as those for the standard gate cannot be tolerated at Palisades Dam where the gates may discharge at partial openings at high heads for long periods of time onto an open stilling basin chute.

Gate slots have been a source of trouble to the Bureau of Reclamation and to other engineering organizations for a long time,

and much work has been done toward developing shapes which will be satisfactory from the viewpoints of design, construction, and hydraulic performance. The major portion of the work done in the past by the Bureau of Reclamation, together with new work which pertains directly to the Palisades gate, will be assembled in a report at a later date. The slot used in the Palisades gate (Figure 17) was developed in the test program to be discussed in the above report.

Experience with the Cedar Bluff model gate indicated that narrow slots created less flow disturbance and spray than wide ones. At Palisades Dam a thick gate leaf is required to withstand, without undesirable bending, the large forces exerted by the water at the high heads. The seeming inconsistency of using a thick gate and narrow slots was resolved by using the full gate thickness across the width of the passage while reducing the thickness at the slots to that required to withstand the shear loads (Figure 17).

A 45-degree sloping bottom was selected for the gate leaf to keep the leaf bottom free from cavitation, to obtain as small a hydraulic downpull as was reasonably possible, and to obtain a smooth water surface on the jet.

Low pressures conducive to cavitation are avoided by using a bottom which slopes rather steeply (Report No. Hyd-130). A slope (measured in the flow direction from the horizontal gate center line to the gate bottom) of 45 degrees was selected as the best compromise between hydraulic and structural considerations.

The magnitude of downpull is determined by the leaf cross-sectional area and the pressure differential between the top and the bottom surfaces. By providing a leaf shape which avoids low pressures on the bottom surface the differential is reduced and unreasonably large downpull forces are avoided.

As previously discussed, a well-distributed and relatively spray-free discharge was desirable since the flow entered an open stilling basin adjacent to the powerhouse. Experience with the Cedar Bluff model gate showed that smooth flow could be obtained by keeping the control point in the gate as far as possible toward the downstream edge of the slots (Report No. Hyd-245). This condition is attained with the sloping gate bottom.

Model Description--Preliminary Design

A model of the preliminary design downstream-seal gate was obtained by modifying the one used in the upstream seal studies (Figure 13). The modifications consisted of transparent slot fillers to reduce the slot width to 0.25 inches and the depth to 0.63 inches; a new leaf 1.32 inches thick in the flow passage and 0.25 inches thick in the slots with a 45-degree sloping bottom; and blocks to narrow the downstream frame and to provide 1-inch (prototype) outward offsets on the downstream

slot corners. The inserts were shaped to converge at a rate of 1:12 to return the passage width to the equivalent of 7 feet 6 inches.

A smooth, well-distributed stream was discharged by this preliminary model of the downstream-seal gate. The stream was readily adaptable to release into either a closed rectangular conduit, an open rectangular chute, or onto a stilling basin apron (Figures 14, 15, and 16). A coefficient of discharge of 0.97 was obtained. This was in line with that sought at the outset of the investigation. On the basis of the performance of this preliminary model a more detailed model was built.

Model Description--Recommended Design

The favorable discharge coefficient of the preliminary downstream-seal design allowed the designers to reduce the height of the prototype gate from 9 feet 6 inches to 9 feet 0 inch, and this change was incorporated in the final model (Figure 17). Narrow gate slots, a thick leaf with the bottom sloped 45 degrees, and a relatively long downstream frame were provided. The outward offset at the downstream slot corners on the side walls and ceiling was 1/2 inch (prototype) and the return of the passage dimensions to the 7-foot 6-inch by 9-foot 0-inch conduit was accomplished with walls that converged at a rate of 1:60 relative to the center line. Piezometers were placed in regions where field experience had shown cavitation damage on prototype structures (Figure 17). The pressures acting on the piezometers were measured with single-leg, water-filled manometers.

It was proposed that the same gate design be used for both the emergency and regulating gates because this allowed lower initial costs and reduced maintenance problems. The gates would be placed in tandem with the regulating gate immediately downstream from the emergency gate. To obtain this tandem arrangement in the model, a dummy gate was made to represent the flow passages of a gate in the wide-open position (Figure 18B). The dummy gate could be attached to either the upstream or downstream side of the operating gate. Piezometers were placed in the roof and on one side wall (Figure 18B). A transition from the 6-inch-diameter inlet pipe to the upstream gate frame dimensions completed the model (Figure 18A). Three piezometers were placed in the transition along the line leading from a 45-degree point on the circular end to the upper left corner of the rectangular end. This line lies along the most rapidly diverging element relative to the conduit center line and was believed to be where the lowest pressures would be encountered in the transition.

Water was supplied to this model through the same piping and measuring system as used in the previous tests.

Model Tests

Downstream gate controlling the flow. To represent the condition where the downstream gate (regulating gate) was used for control,

the model gate was placed on the downstream side of the dummy gate. Water discharged smoothly at heads up to the equivalent of 400 feet, and at all gate openings except between 97 and 100 percent of full open. Between 97 and 100 percent open the water tended to cling to the roof of the downstream frame, and rough flow resulted. At 100 percent open the water was in full contact with the roof, and smooth flow was again obtained. At openings less than 97 percent the water jumped free from the roof and smooth flow occurred. The flow characteristics at a total equivalent head of 240 feet and at gate openings of 100, 60, 40, and 20 percent are shown in Figure 19. Fine spray came from the corners formed by the gate leaf bottom and the sides of the gate frame. Thin fins formed along the walls of the downstream frame. The coefficient of discharge versus gate opening curves for a single gate and for the tandem arrangement are shown in Figure 20.

Pressure measurements obtained from the piezometers in the passage walls, and expressed in feet of water, are shown in Figure 21A. At 100 percent gate opening and at a total head of 240 feet, the pressures on the roof and on the side walls 3 inches below the roof were positive just downstream from the gate slot, and became negative to the extent of 4.4 feet near the end of the frame. All the remaining side wall, gate slot, floor, and transition pressures were positive. At 99 percent open, the roof pressures just downstream from the slot were negative to the extent that cavitation would occur on the prototype if no air were admitted. The rest of the pressures were about the same as at 100 percent open. At 98 percent open, part of the water still remained in contact with the roof, but no negative pressures greater than 1.6 feet of water were found. At all smaller gate openings and at all heads tested the gate slot, side wall, and floor pressures were positive.

The extreme negative pressures on the roof at 99 percent gate opening were undesirable. To relieve these low pressures, eight 3/32-inch-diameter air vents were drilled into the roof of the downstream frame along a line that was the equivalent of 3 inches downstream from the gate slot (Figure 17). The vents supplied sufficient air to limit the negative pressures to values not greater than 5.7 feet of water (Figure 21A). Better venting would have made the pressures more nearly atmosphere. No attempt was made to measure the amount of air drawn through the vents, but apparently it was nominal because the model air passages were not conducive to high rates of flow. The important consideration for the prototype structure is that air be admitted across the full width of the roof in a band as close to the gate leaf as structural considerations permit.

Upstream gate controlling the flow. To represent the condition where the upstream (emergency) gate would be the control, the model gate was placed ahead of the dummy gate. Water discharged in the same manner as when the downstream gate controlled, and slightly larger side wall fins were formed, probably due to the greater length of wall below the control gate (Figure 22). Smooth flow occurred at all gate openings

except between about 97 and 100 percent full open. When air was not admitted at the vents the water tended to cling to the roof longer than previously because the passage was longer and there was less opportunity for air to move back from the end of the downstream gate. As expected, the roof pressures were very low at gate openings of 98 and 99 percent when the air vents were closed (Figure 21B). The rest of the pressures were similar to those in the previous tests, but were higher by the slight amount that the hydraulic grade line was increased. At 97 percent open the water was springing free of the roof, and the roof pressures became approximately atmospheric. Good flow occurred at 100 percent opening. The admission of air through the vents limited the most severe negative pressures in the roof to 11.5 feet of water, prototype. Better venting would made these pressures more nearly atmospheric.

The pressures in the roof downstream from the gate slot in the downstream (dummy) gate were not greatly affected by the low pressures near the preceding gate and remained very slightly negative whenever the conduit was full. These slight negative pressures were of about the same magnitude as those which would occur on the top surfaces at the end of a straight pipe which is discharging horizontally into the atmosphere.

The pressures on the walls and floor of the upstream gate frame at openings of 15, 10, and 5 percent and at a total head of 240 feet are shown in Figure 21B. All were positive. The pressures on the wall 6 inches above the floor in the downstream gate (Station 13) when the upstream gate is regulating are positive near the slot and become negative to a maximum value of 2.20 feet near the end of the frame. The pressures were measured at control gate openings of 100, 99, 98, and 20 percent and at a constant total head of 240 feet (Figure 21B).

Gate discharging underwater. A special research program was made with the recommended design model gate to determine the pressures that would occur on this type of gate in the event that it were used underwater. The gate was placed at the end of a 6-inch supply line in such a manner that it could discharge into a tail box (Figure 23A). Triangular baffles in the box broke up the flow to produce a more quiet water surface, and a tailgate allowed regulation of the water depth above the model gate. The gate was tested in arrangements where it discharged either directly into the pool, or into a 12-inch-long rectangular conduit leading to the pool (Figures 23B and C).

The pressures obtained on the gate are presented in the nondimension form of pressure coefficients wherein the coefficient (or pressure factor) equals the pressure difference between the particular piezometer and the reference piezometer, divided by the velocity head at the reference station. The reference piezometer was taken at a point in the 6-inch supply pipe 1 diameter upstream from the inlet transition (Figure 23A). The tabulated pressure coefficients for the gate discharging directly into the pool are shown in Figure 24. Those for discharge

into the short conduit are shown in Figure 25. The coefficient of discharge versus gate opening curves for the two types of operation are shown in Figures 26A and B, respectively.

These data may be applied to any general situation in the following manner. First, determine the rate of flow by means of the gate opening, gate and conduit size, the coefficient of discharge at the opening, and the total head differential across the gate. Having obtained the flow rate, compute the velocity head at the reference point. The pressure coefficient for the particular piezometer may then be multiplied by this velocity head to give the pressure change, in feet of water, from the piezometer to the reference station. The pressure change, added algebraically to the reference station pressure, will give the piezometric pressure to be expected at the particular location. The pressure at the reference station is found by adding the submergence to the head given by the relation $\left(\frac{1}{C_d^2} - 1\right)\frac{V_R^2}{2g}$.

In general, the gate operates satisfactorily as a regulating device in submerged installations provided there is adequate water depth (or pressure) above it. As with most control devices when used underwater, severe cavitation can occur if the gate is placed in an improper set-up. The above data may be used to examine future structures using this design slide gate to insure that adequate submergence is provided for the head differentials at which the gate is to operate.

For reference purposes the prototype design of the Palisades 7-foot 6-inch by 9-foot 0-inch slide gate is shown in Figures 27 and 28.

Interior - Reclamation - Denver, Colo.

FIGURE 1
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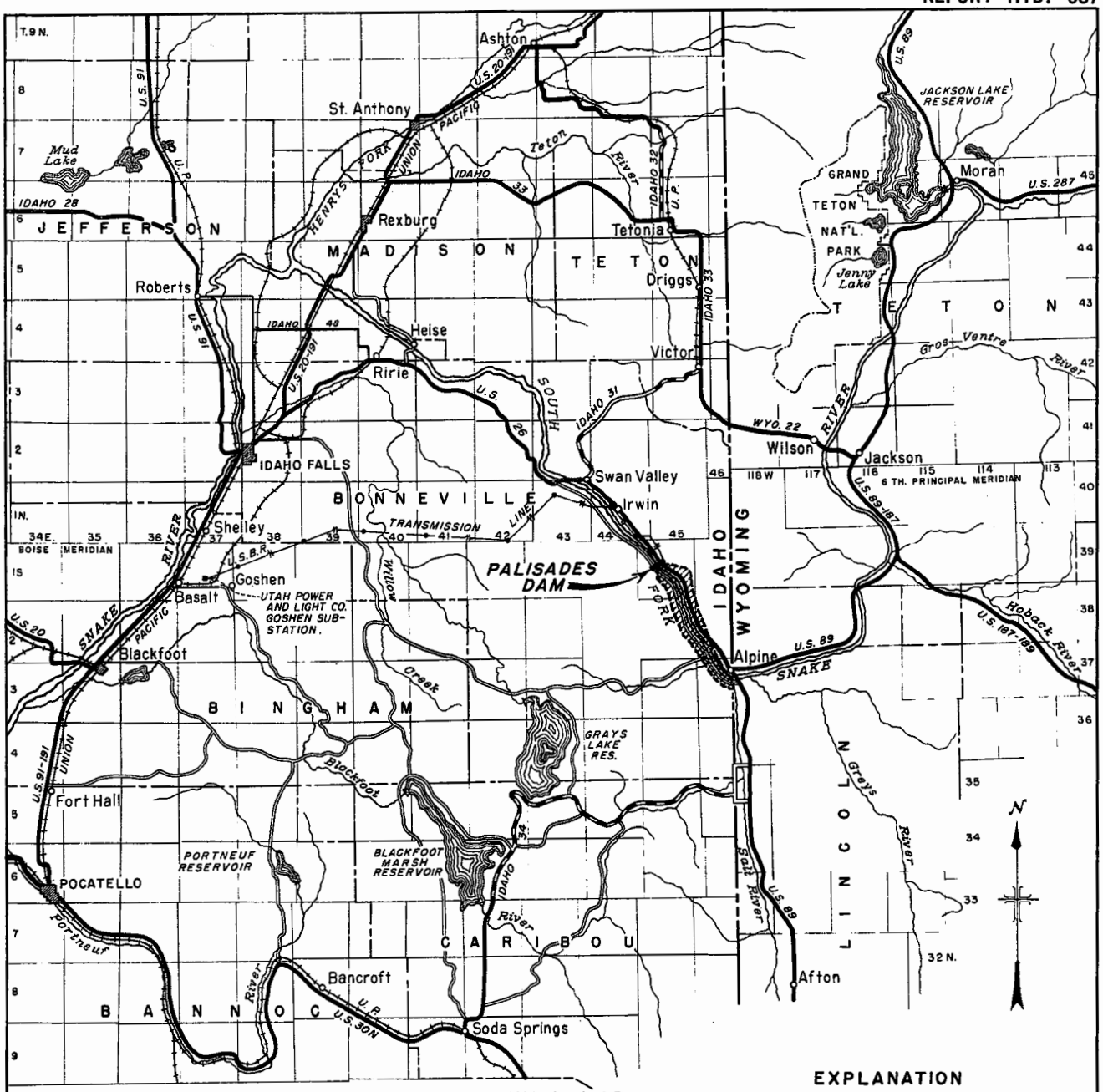
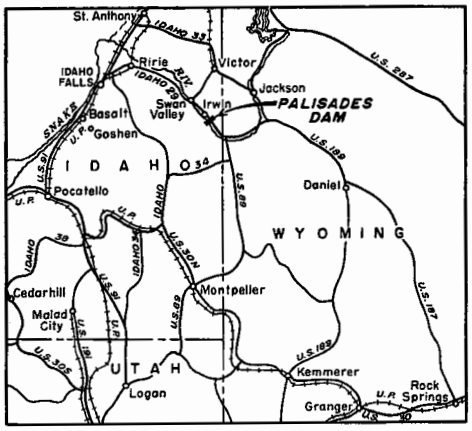


VICINITY MAP

EXPLANATION

- PAVED ROAD
- IMPROVED ROAD
- DIRT ROAD

5 0 5 10 15 20 25
SCALE OF MILES



INDEX MAP

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PALISADES PROJECT-IDAHO
PALISADES DAM
LOCATION MAP

DRAWN G.H.T.	SUBMITTED		
TRACED G.M.A.	RECOMMENDED		
CHECKED	APPROVED	ACT. CHIEF ENGINEER	
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FIGURE 2
REPORT HYD. 387

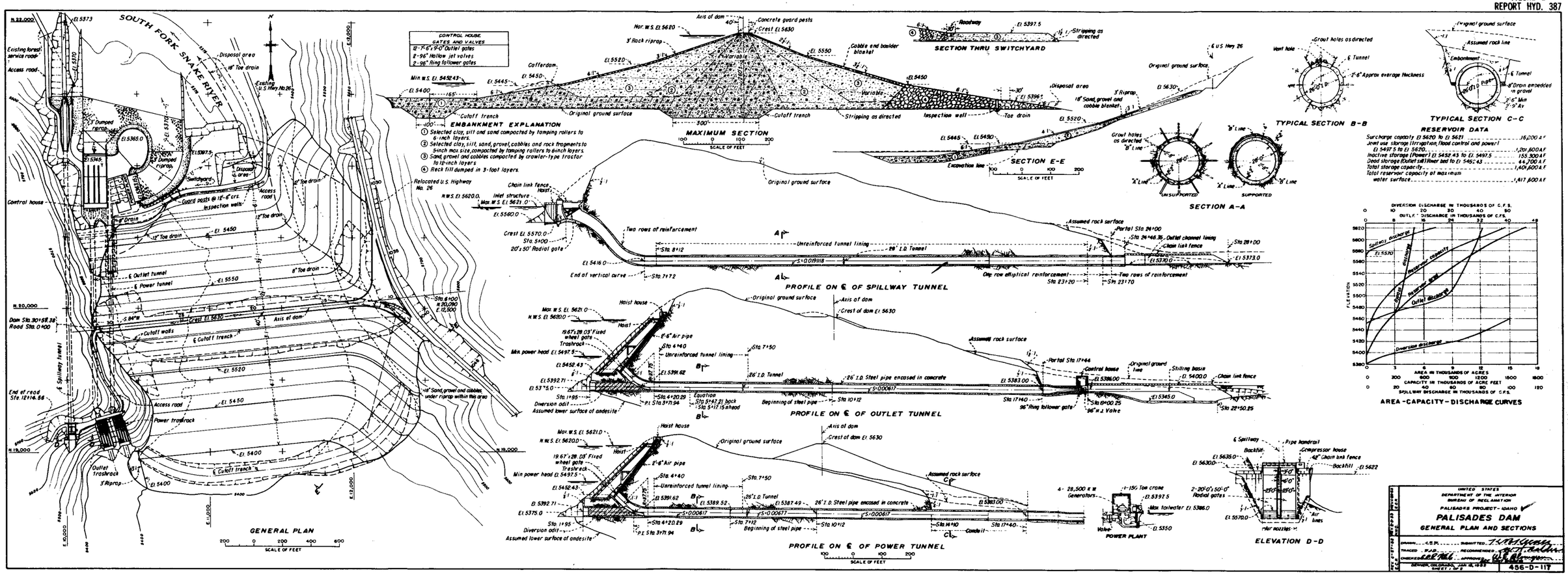

FIGURE 3
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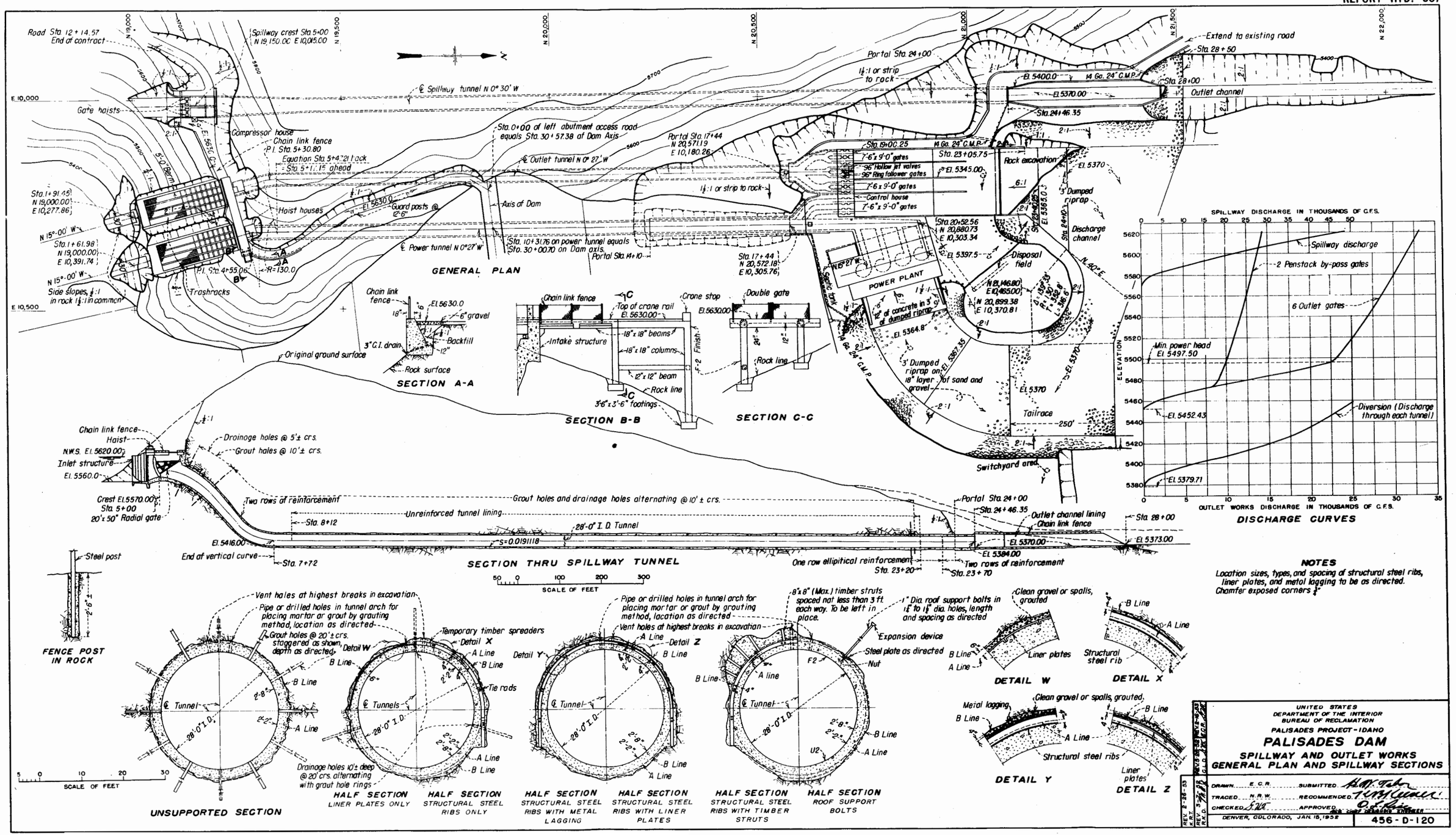
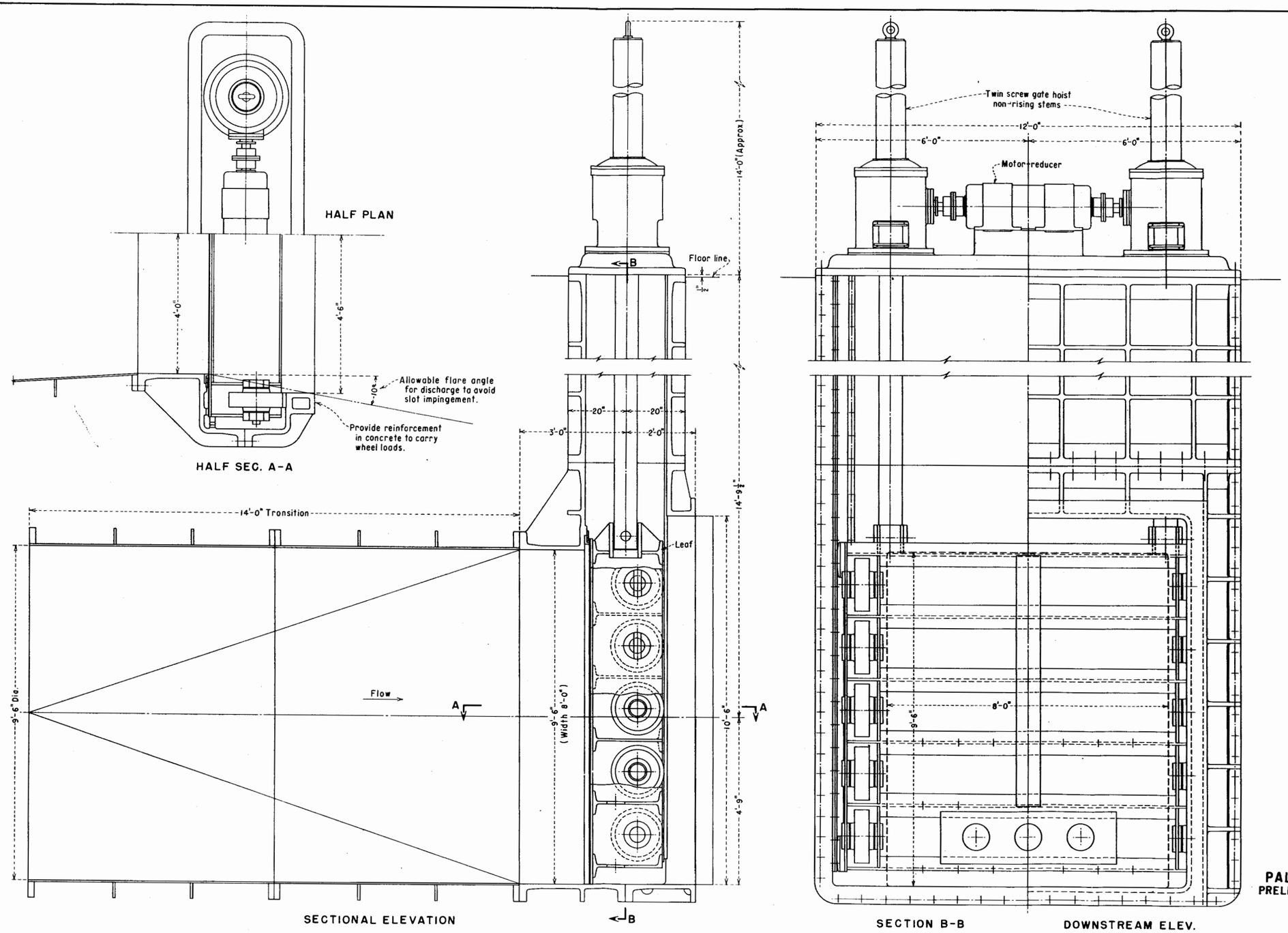
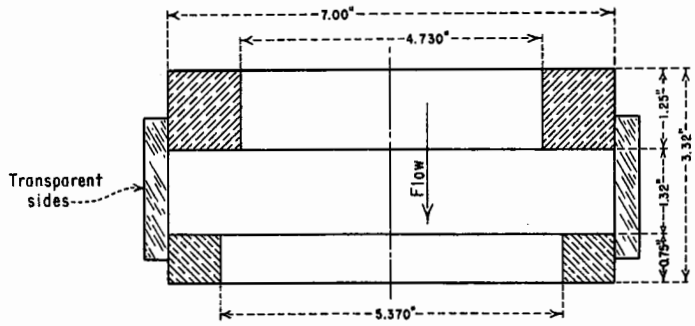
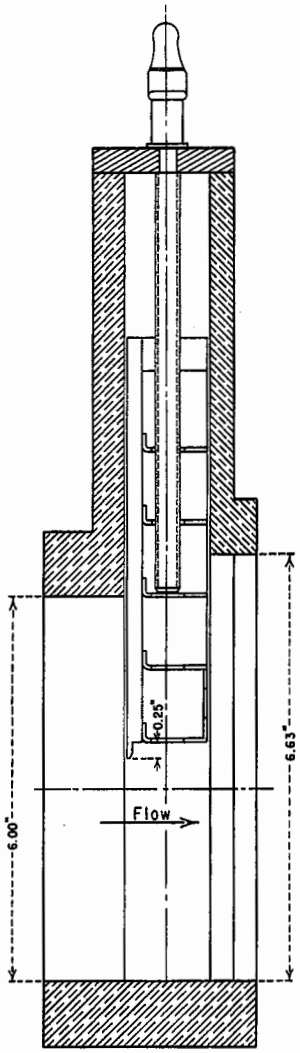




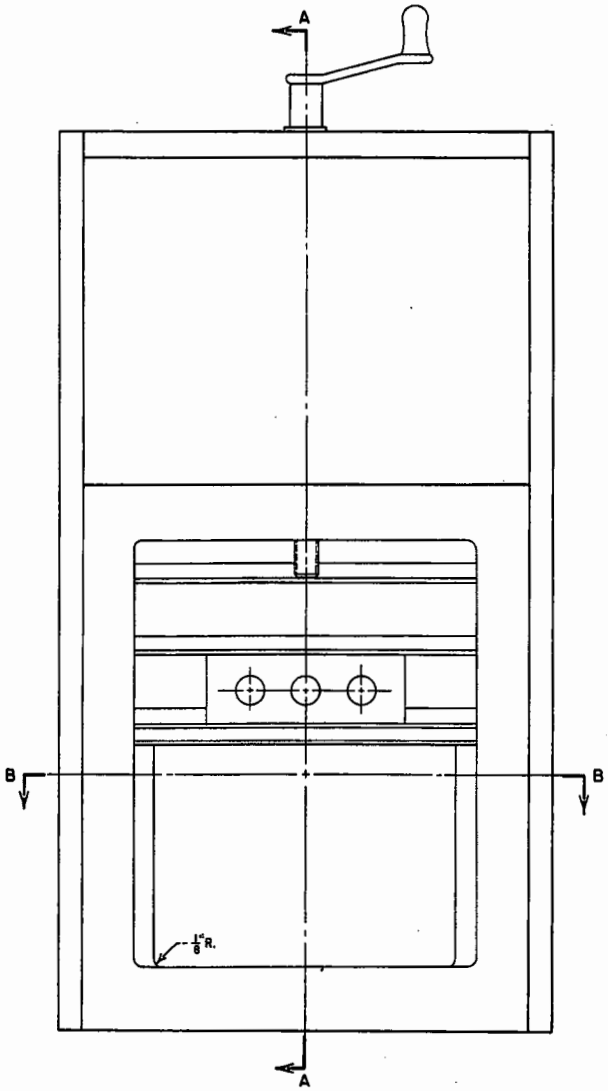
PALISADES REGULATING SLIDE GATE
PRELIMINARY 8'-0" x 9'-6" UPSTREAM SEAL GATE



SECTION B-B



SECTION A-A



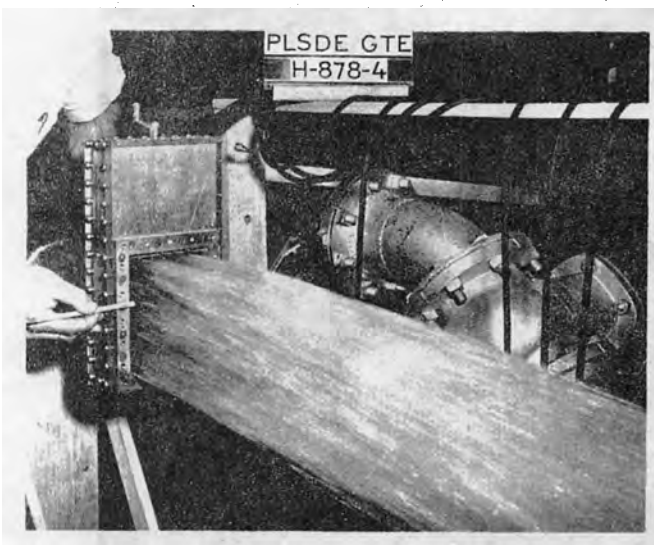
VIEW LOOKING UPSTREAM

PALISADES REGULATING SLIDE GATE

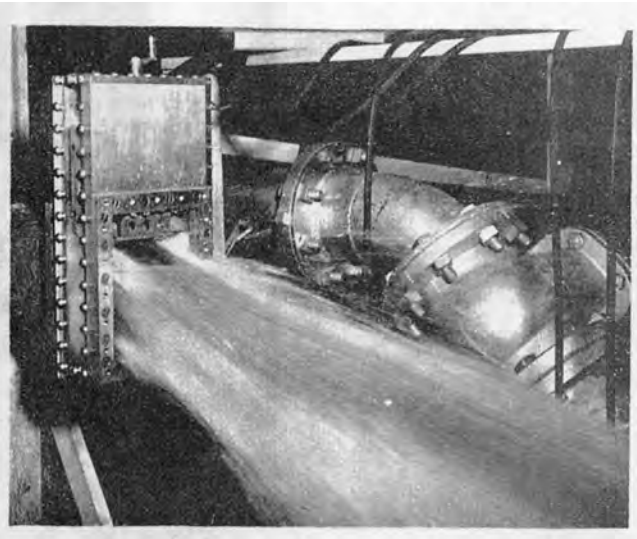
PRELIMINARY DESIGN 7'-6" x 9'-6" UPSTREAM SEAL GATE

1 : 19 Scale Model

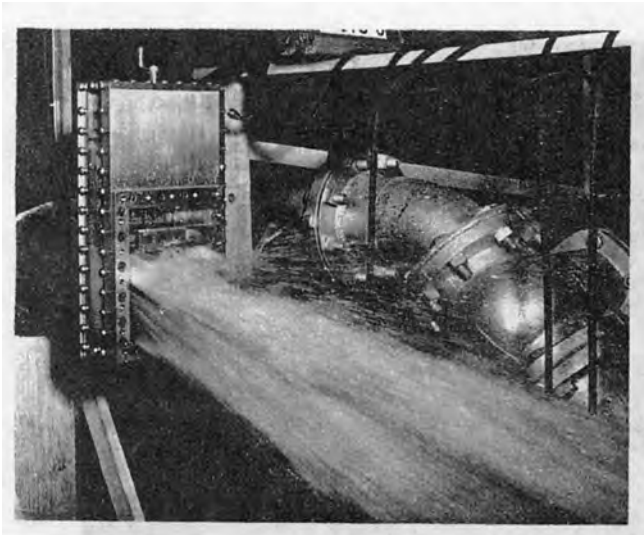
346



A. Full open



B. 83% open

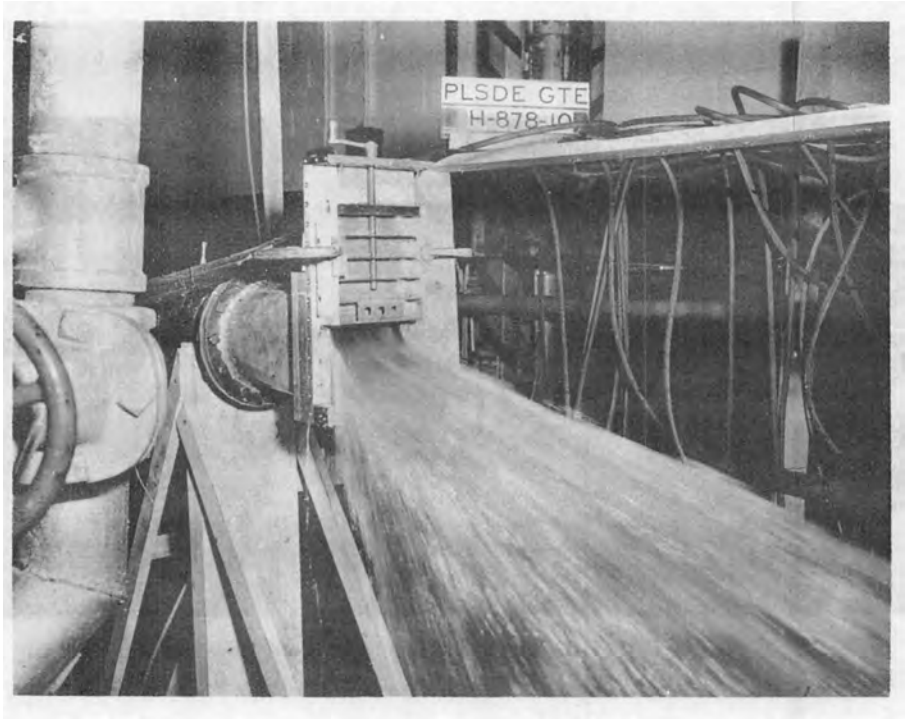


C. 67% open

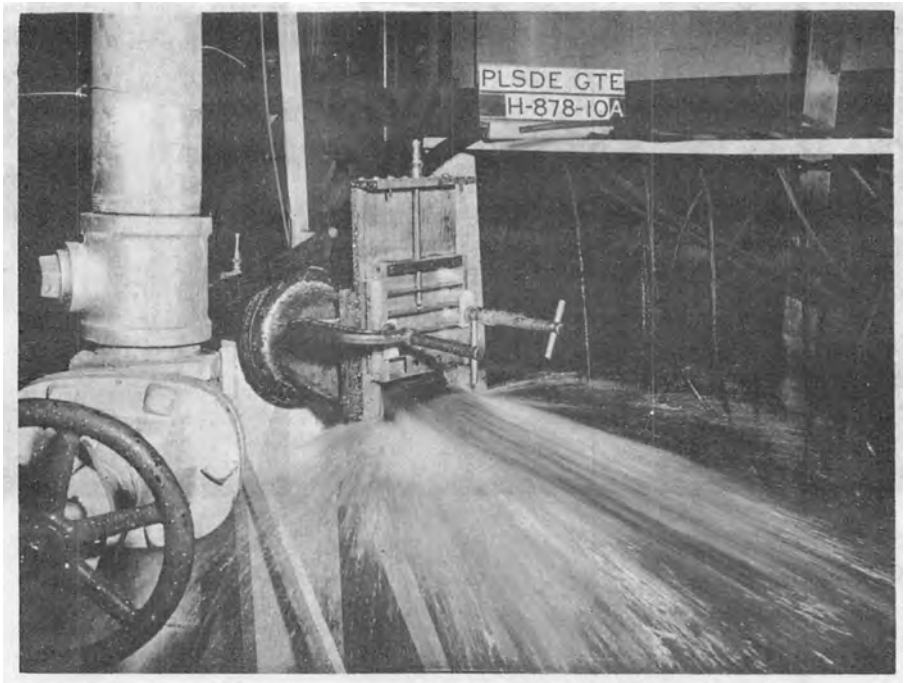
D. 17% open

PALISADES REGULATING SLIDE GATE
Preliminary design, 7' - 6" x 9' - 6" Upstream Seal Gate
Flow conditions for 1:19 scale model at an
equivalent head of 240 feet

Figure 7
Report Hyd 387

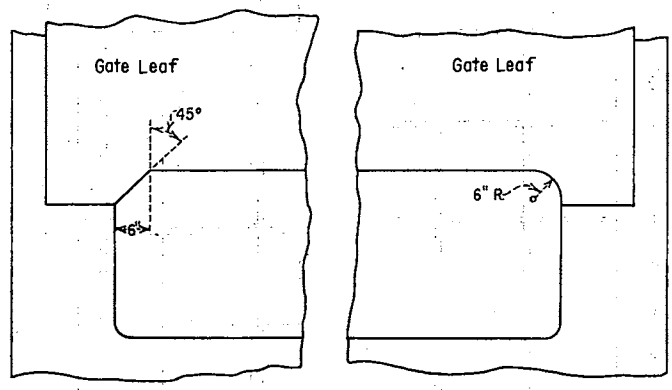


A. 67% open



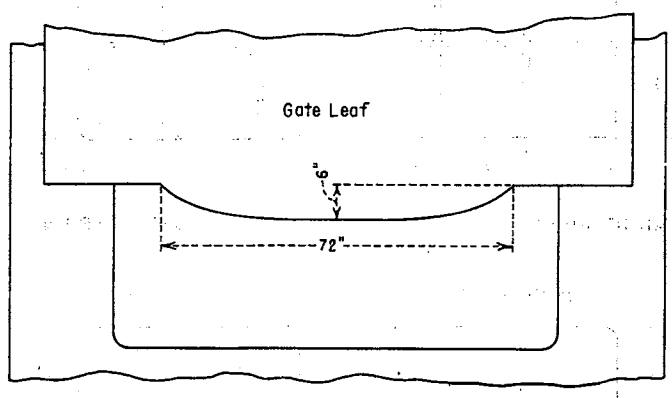
B. 17% open

PALISADES REGULATING SLIDE GATE
Preliminary Design, 7' - 6" x 9' - 6" Upstream Seal Gate
Flow conditions for 1:19 scale model with downstream
frame removed and equivalent head of 240 feet

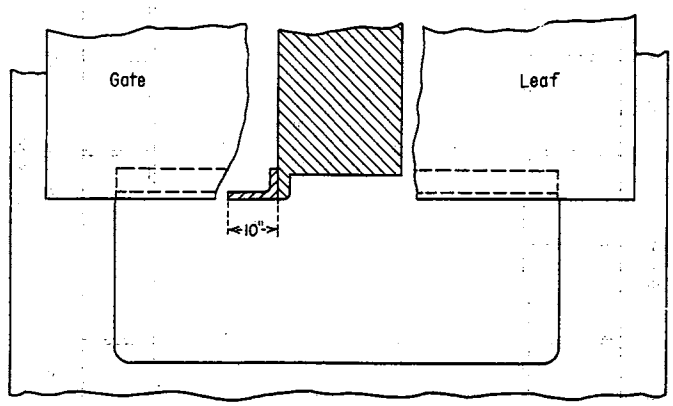


45°-6" CORNER BLOCK

6" RADIUS CORNER BLOCK



6" DEEP CENTER BLOCK

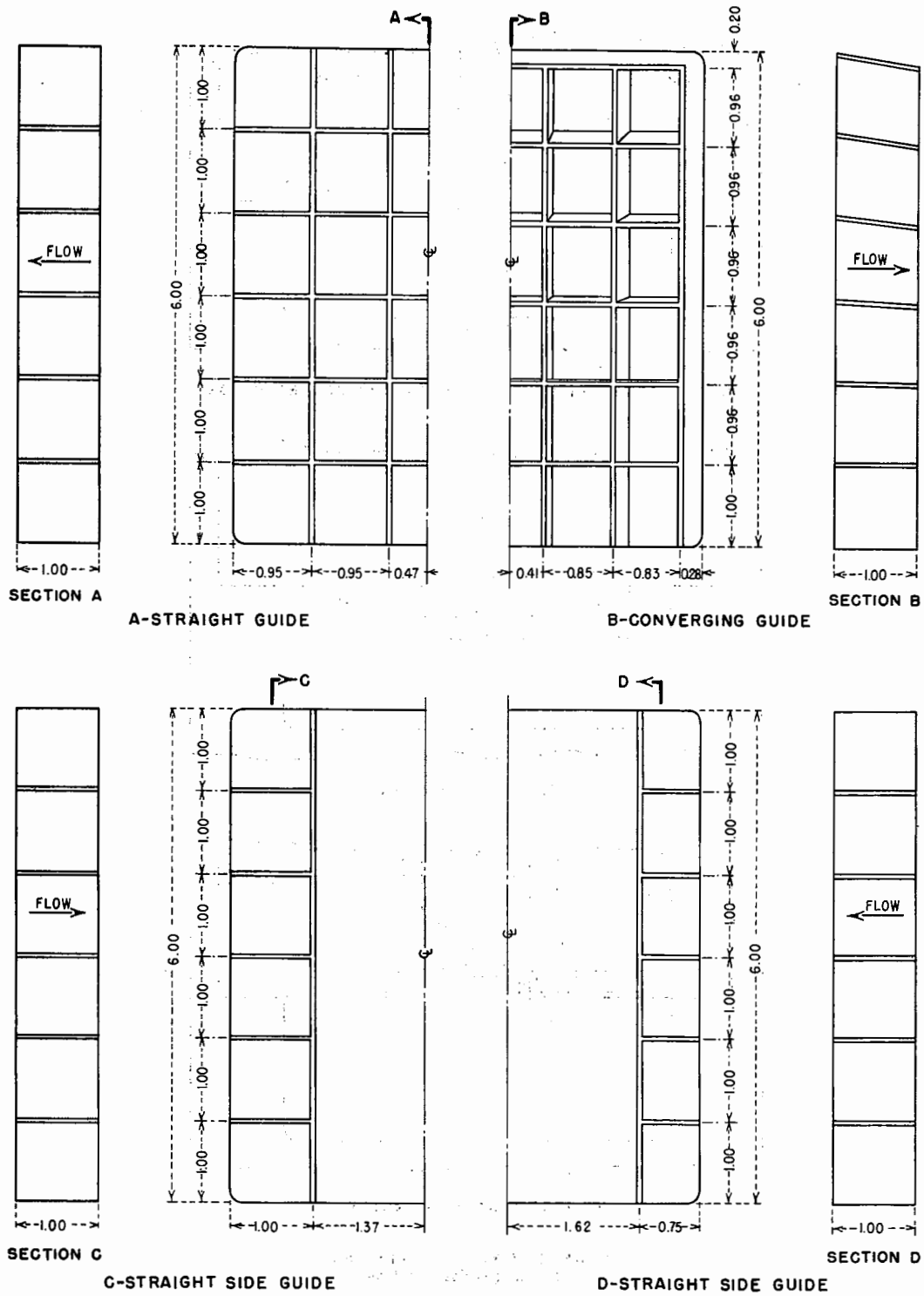


10" UPSTREAM EXTENSION

VIEWS LOOKING UPSTREAM
-Dimensions given as prototype

PALISADES REGULATING SLIDE GATE
PRELIMINARY DESIGN 7'-6" x 9'-6" UPSTREAM SEAL GATE
EXTENSIONS FOR 1:19 SCALE MODEL GATE LEAF BOTTOM

FIGURE 9
REPORT HYD 387

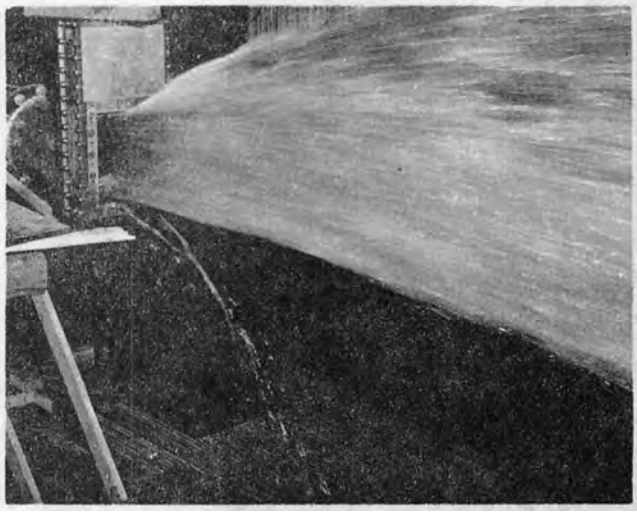


PALISADES REGULATING SLIDE GATE

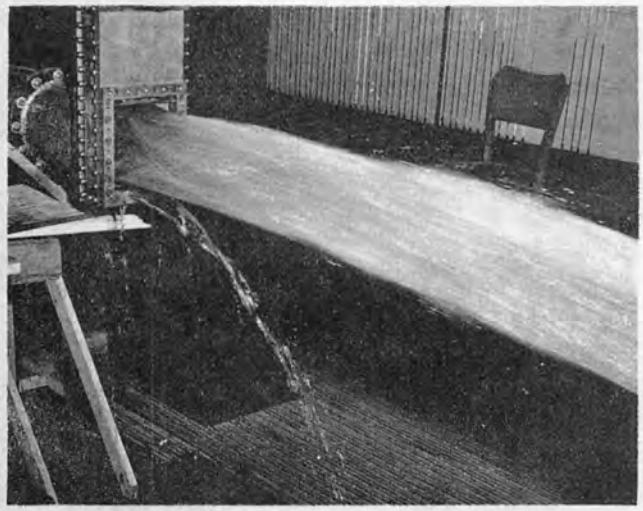
PRELIMINARY DESIGN 7'-6" x 9'-6" UPSTREAM SEAL GATE

FLOW GUIDES UPSTREAM FROM 1:19 SCALE MODEL GATE LEAF

346

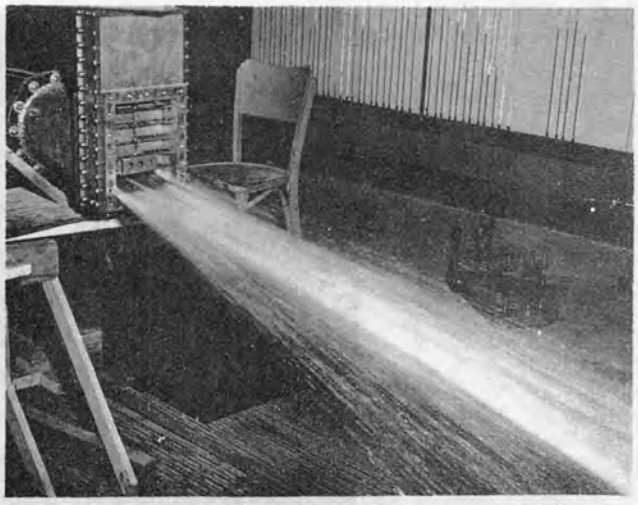


A. Full open



B. 97% open

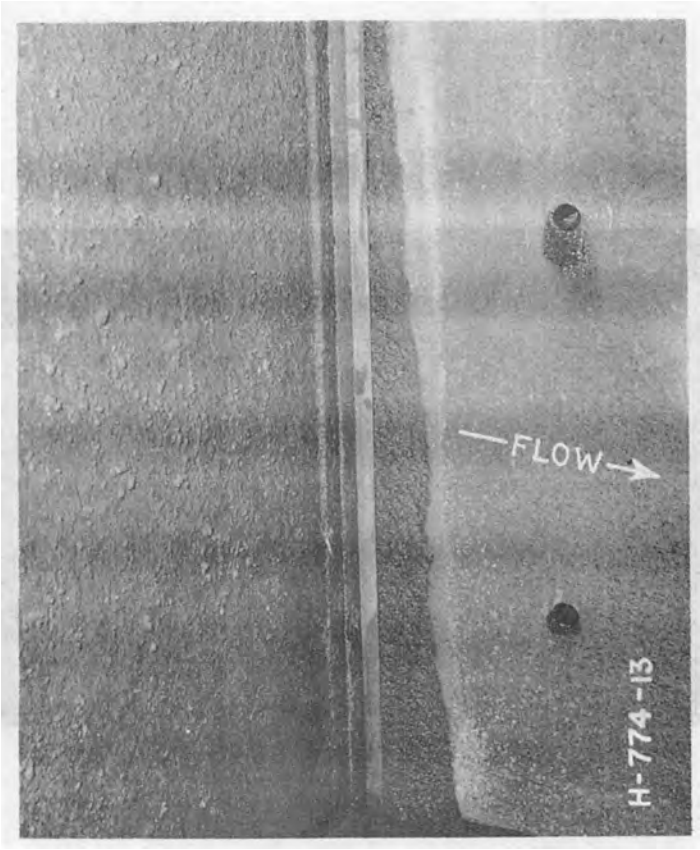
C. 67% open



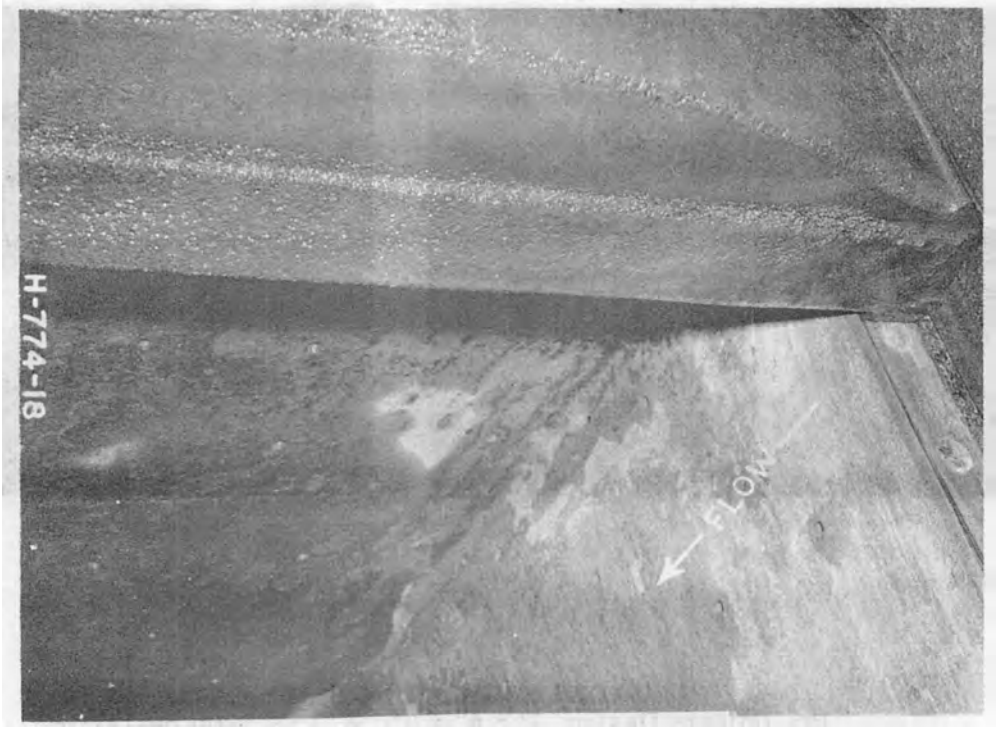
D. 17% open

PALISADES REGULATING SLIDE GATE
Preliminary Design, 7' - 6" x 9' - 6" Upstream Seal Gate
Flow conditions for 1:19 scale model with equivalent of
4-inch, 90° sidewall deflectors; a 6-inch, 90° floor deflector,
and a 240-foot head

Figure 11
Report Hyd 387

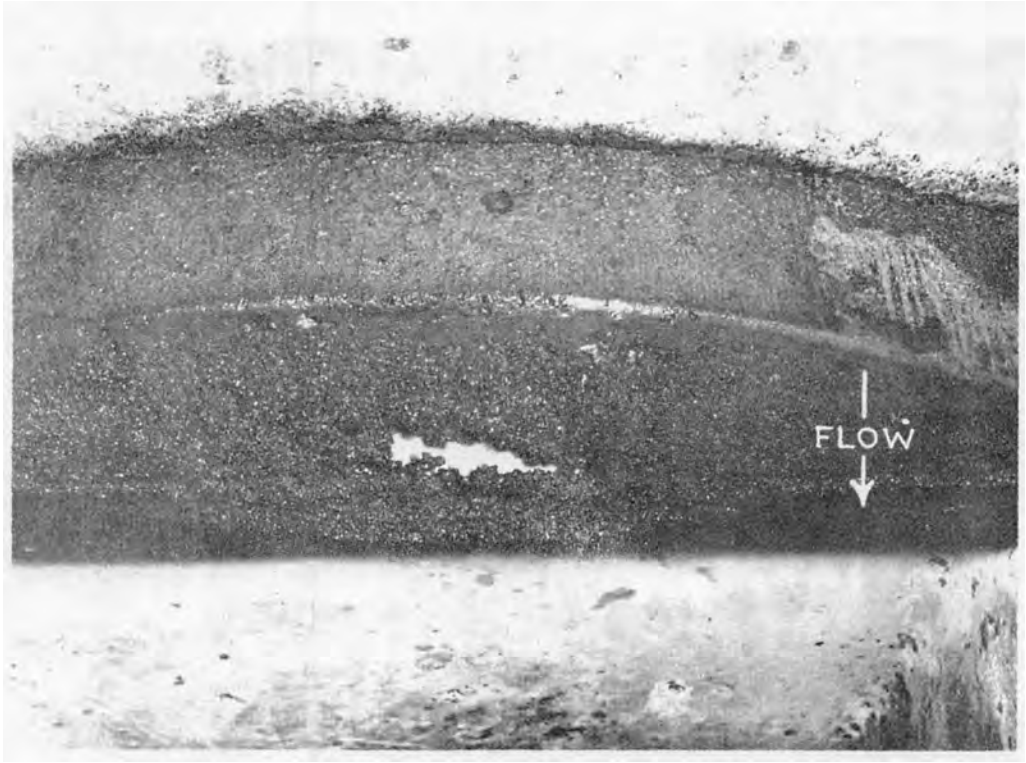


A. Cavitation in conduit below gate leaf on left side of right service gate

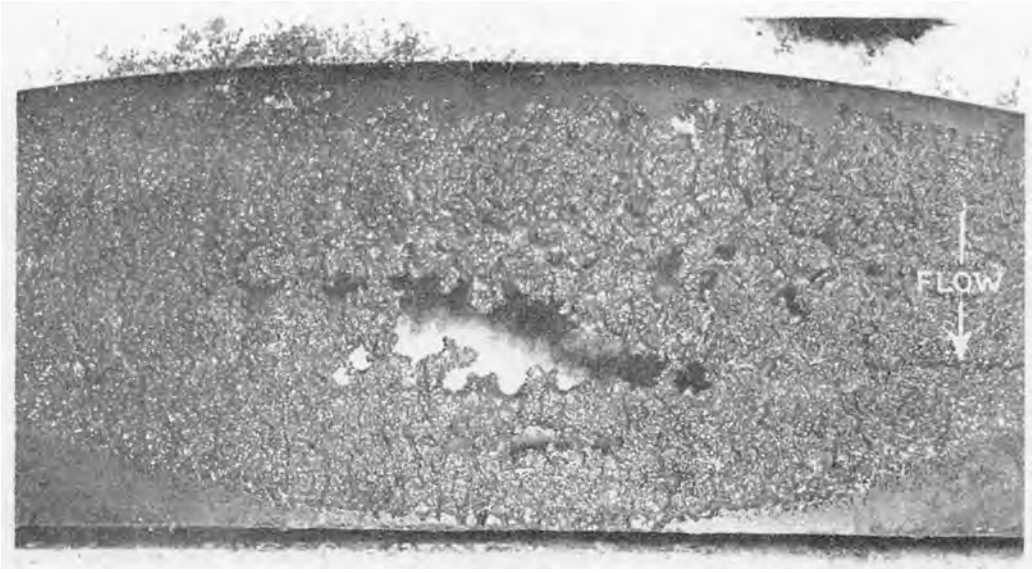


B. Cavitation on bottom of gate leaf on left service gate

PALISADES REGULATING SLIDE GATE
Cavitation damage on standard Slide Gates at Caballo Dam

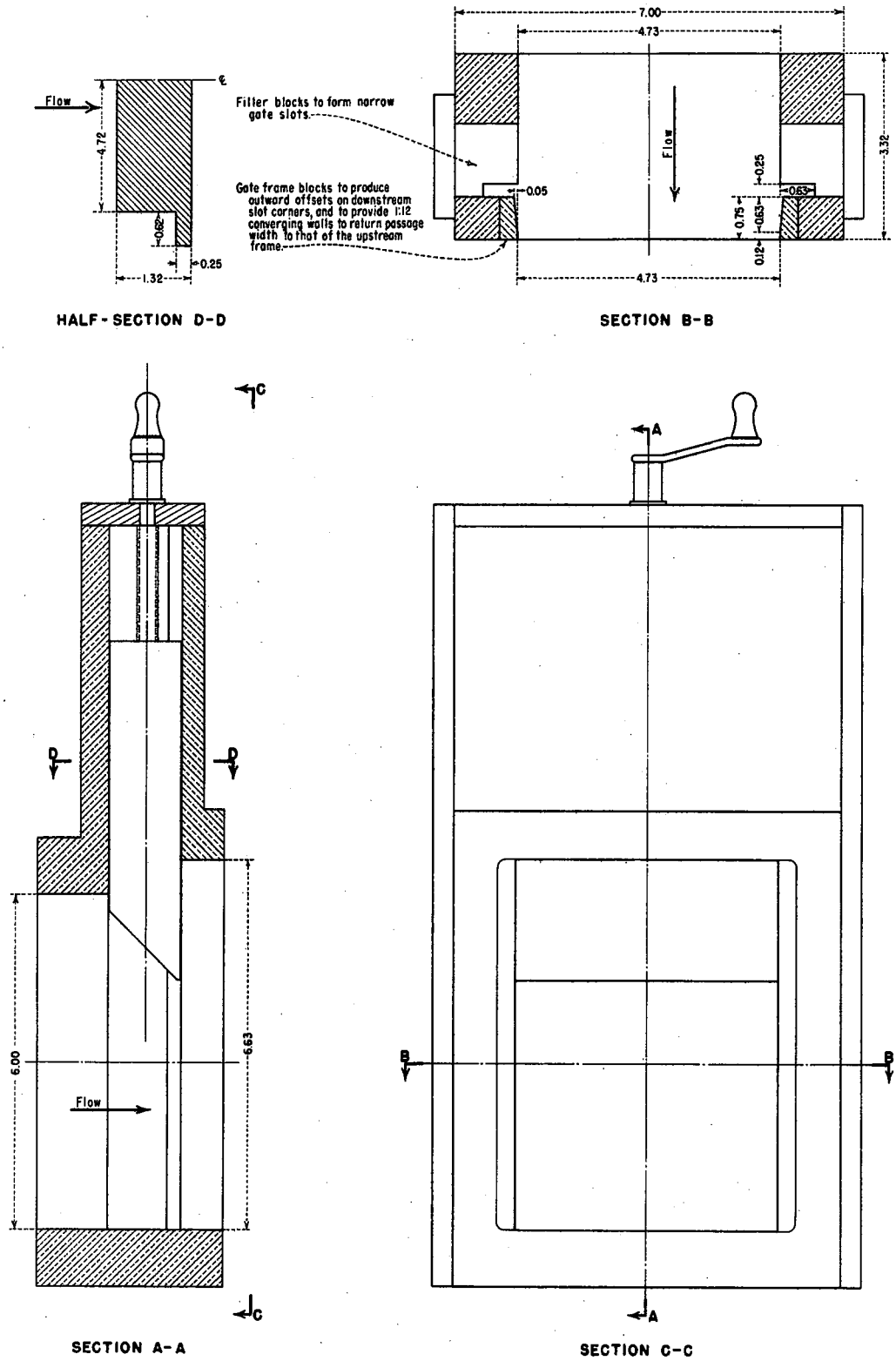


A. Bottom of leaf in right outlet gate, looking downstream



B. Closeup of leaf bottom showing large areas eroded through the metal

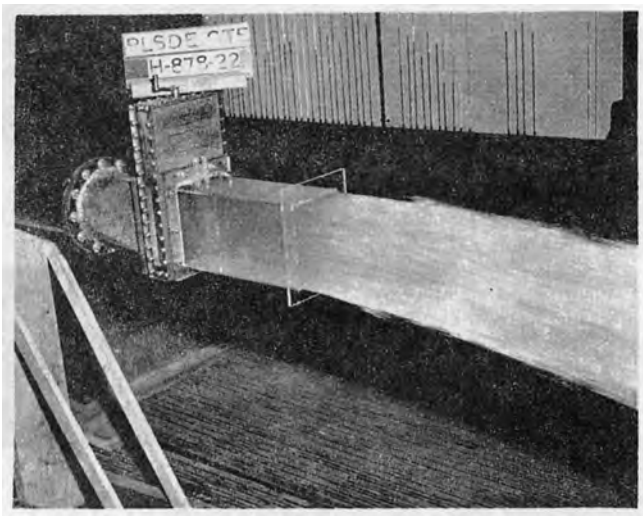
PALISADES REGULATING SLIDE GATE
Cavitation damage on "Standard" slide gates at Rye Patch Dam



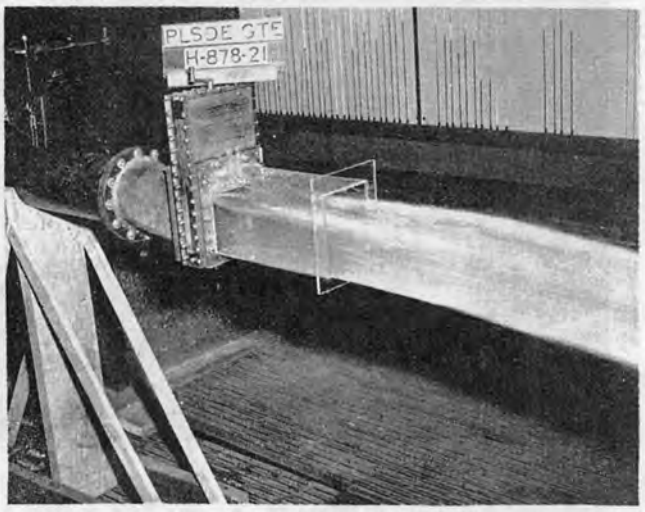
PALISADES REGULATING SLIDE GATE

PRELIMINARY DESIGN 7'-6" x 9'-6" DOWNSTREAM SEAL GATE

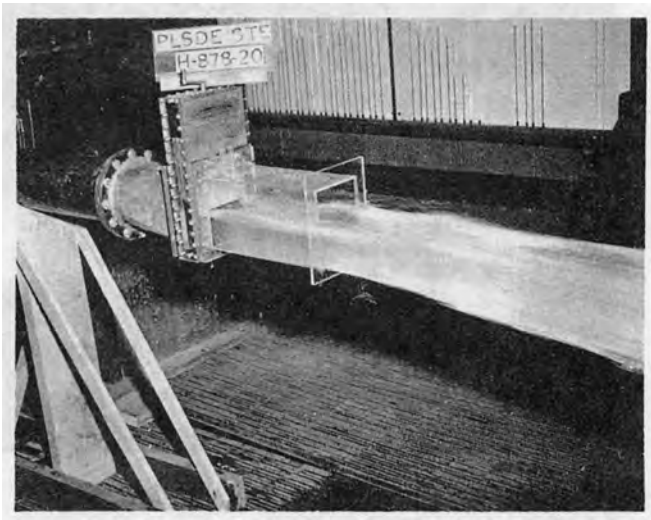
1 : 19 Scale Model



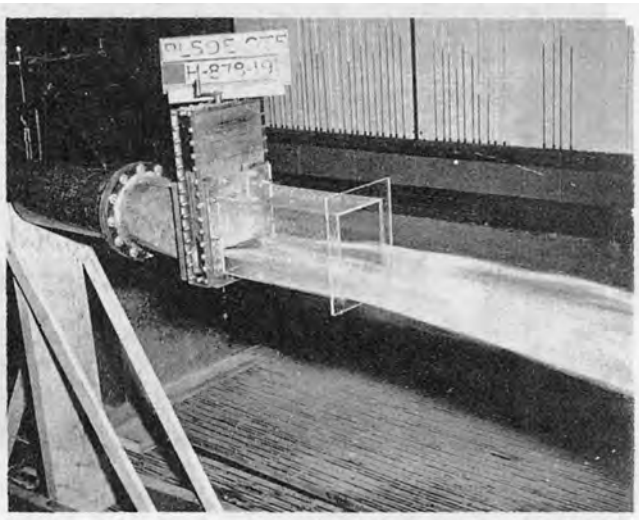
A. Full open, 8600 cfs



B. 75% open, 5500 cfs



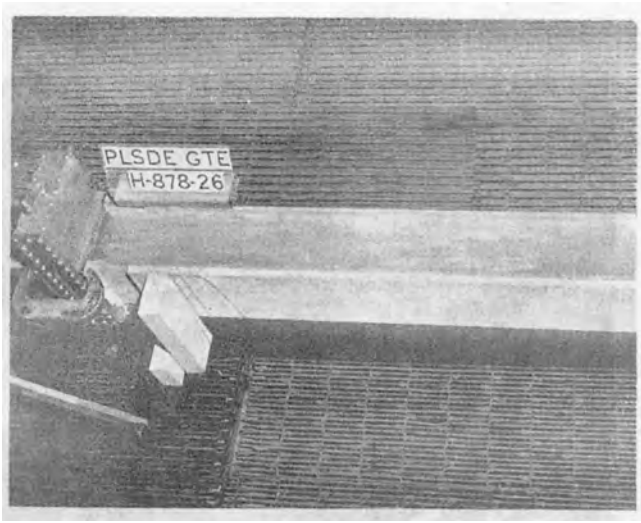
C. 50% open, 3500 cfs



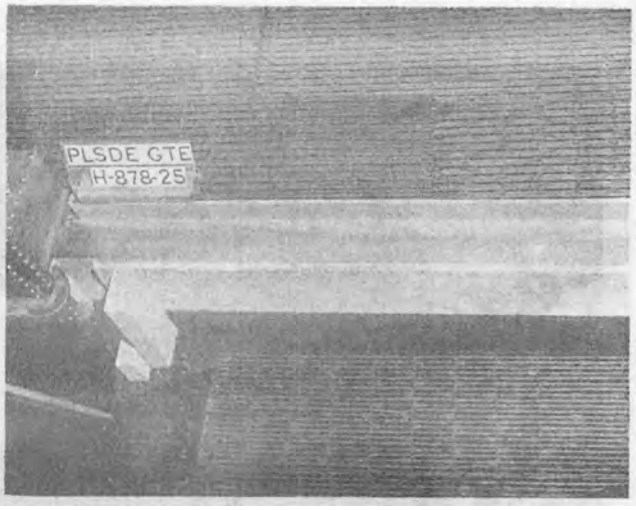
D. 25% open, 1860 cfs

PALISADES REGULATING SLIDE GATE
Preliminary Design, 7' - 6" x 9' - 6" Downstream Seal Gate
Flow conditions for 1:19 scale model with the
equivalent of 19 feet of gate-sized conduit downstream,
and a 240-foot head

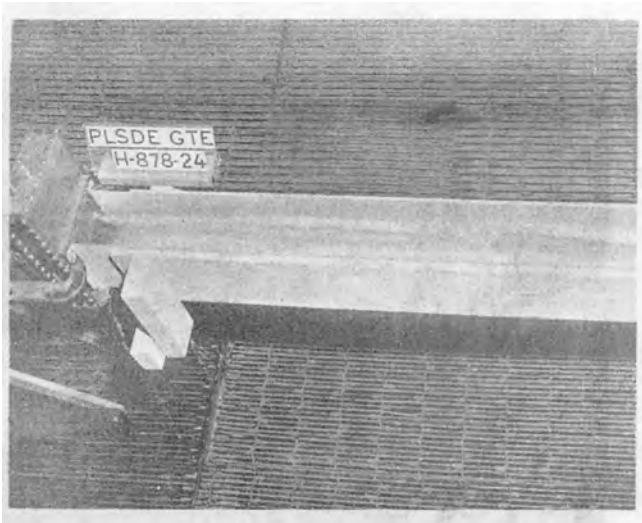
Figure 15
Report Hyd 387



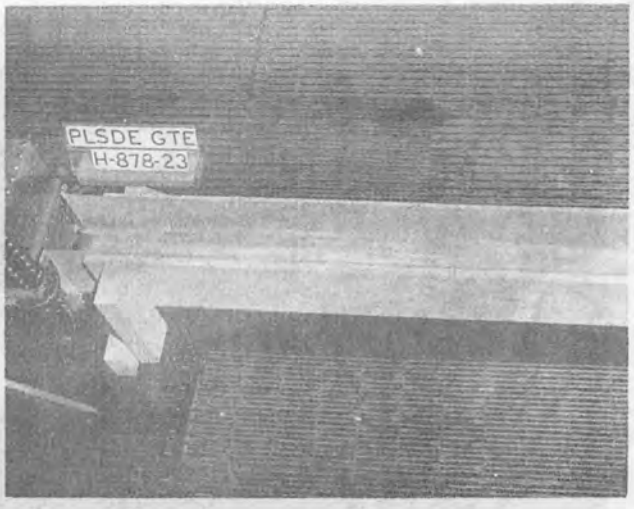
A. Full open, 8600 cfs



B. 75% open, 5500 cfs

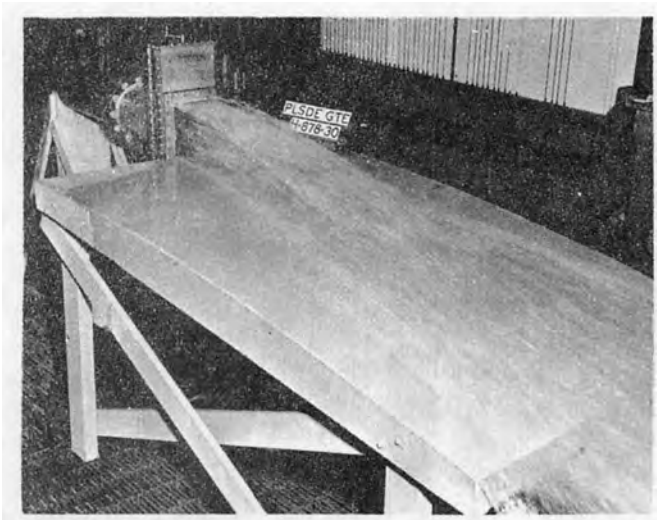


C. 50% open, 3500 cfs



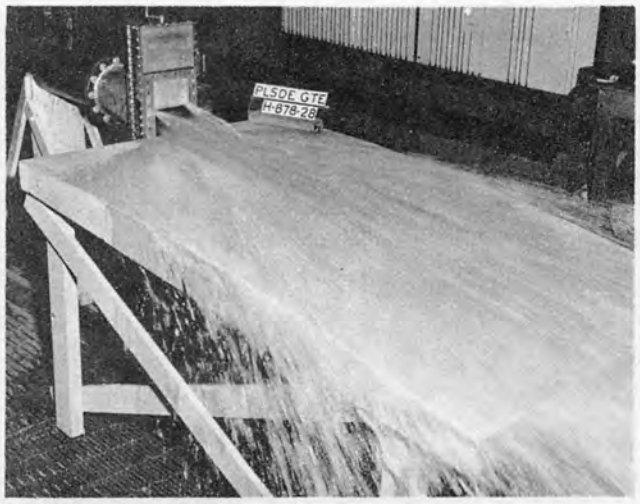
D. 25% open, 1860 cfs

PALISADES REGULATING SLIDE GATE
Preliminary Design, 7' - 6" x 9' - 6" Downstream Seal Gate
Flow conditions for 1:19 scale model with the
equivalent of a 7' - 6"-wide chute downstream, and
a 240-foot head



A. Full open, 8600 cfs

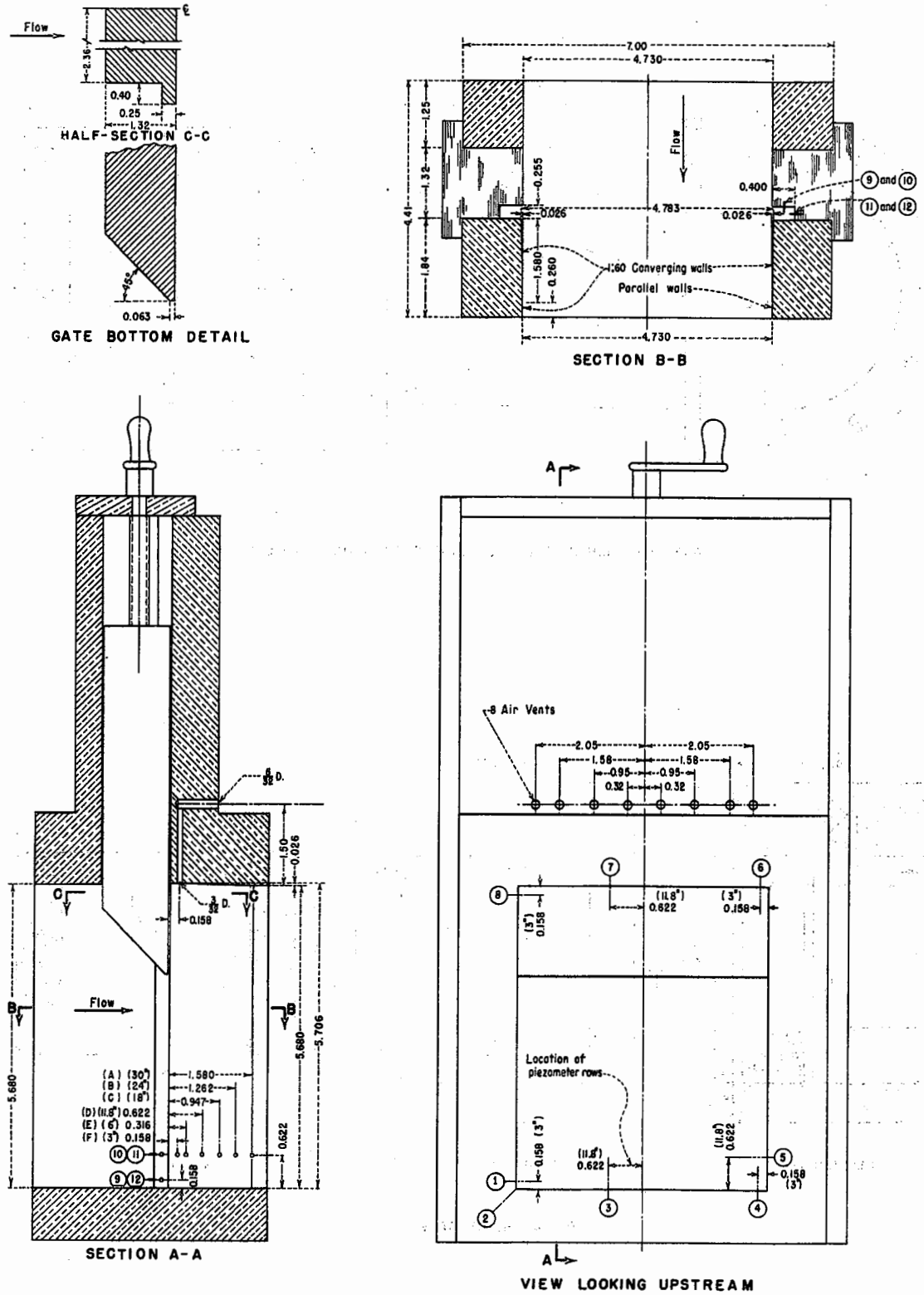
B. 75% open, 5500 cfs



C. 50% open, 3500 cfs

D. 25% open, 1860 cfs

PALISADES REGULATING SLIDE GATE
Preliminary Design, 7' - 6" x 9' - 6" Downstream Seal Gate
Flow conditions for 1:19 scale model with curved stilling basin apron downstream and equivalent head of 240 feet

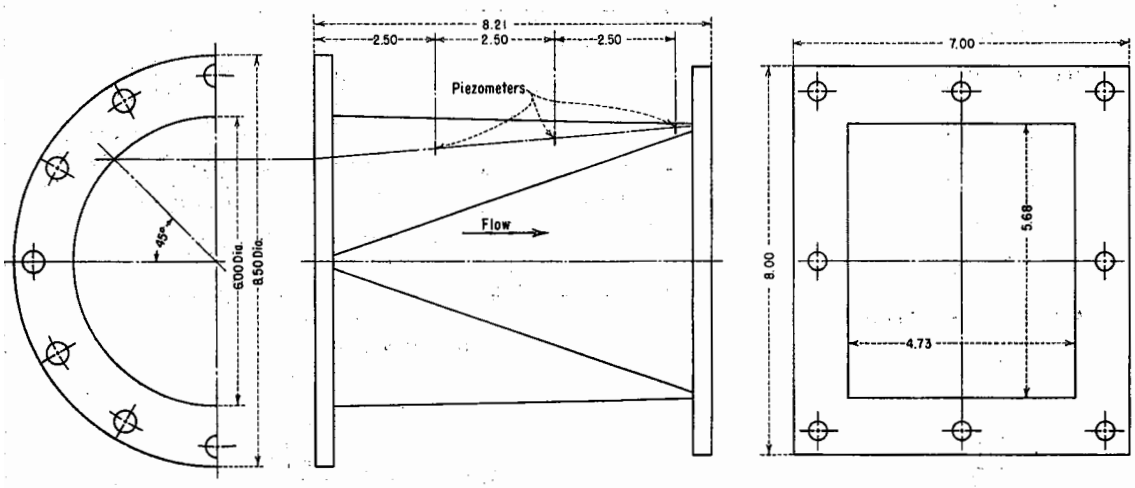


(1), etc,- indicates station of piezometers
(5'), etc,- prototype distance
(A), etc,- piezometer designation

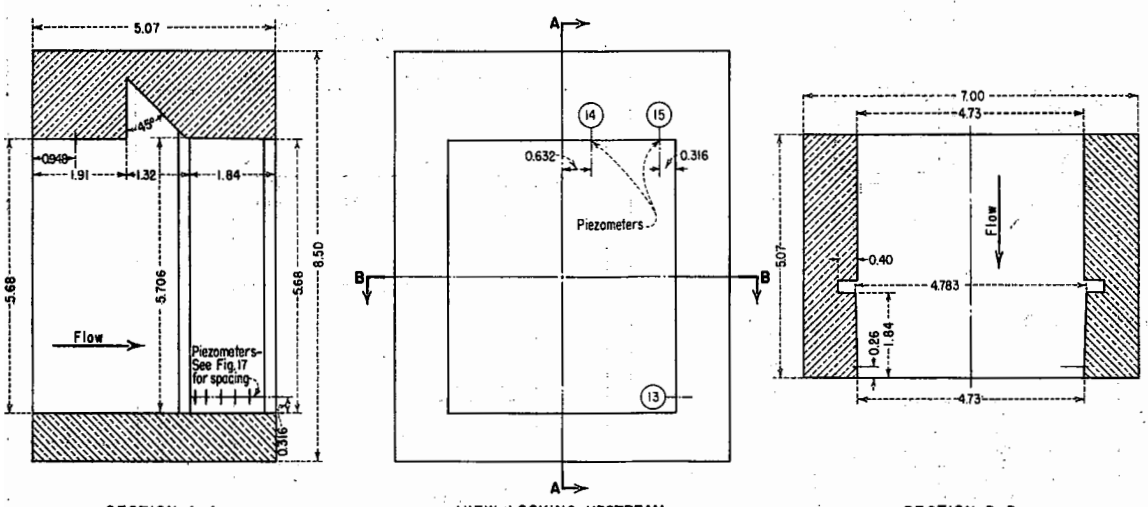
PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6" x 9'-0" DOWNSTREAM SEAL GATE

1 : 19 Scale Model



TRANSITION FROM CIRCULAR CONDUIT TO RECTANGULAR GATE



SECTION A-A

VIEW LOOKING UPSTREAM

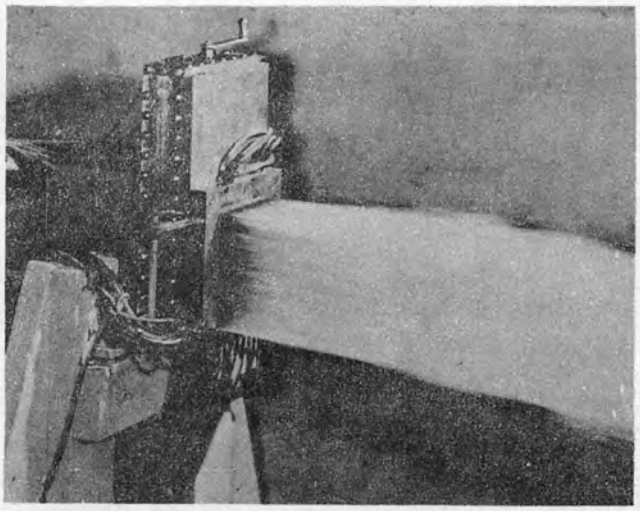
SECTION B-B

DUMMY SLIDE GATE

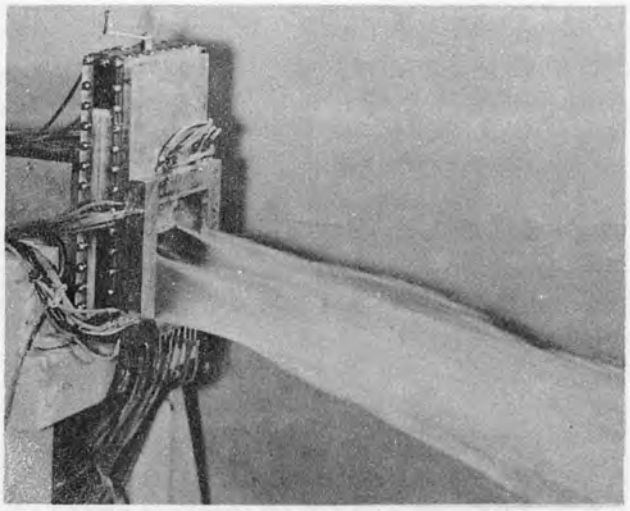
PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN CONDUIT TRANSITION AND 7'-6" x 9'-0" DUMMY SLIDE GATE

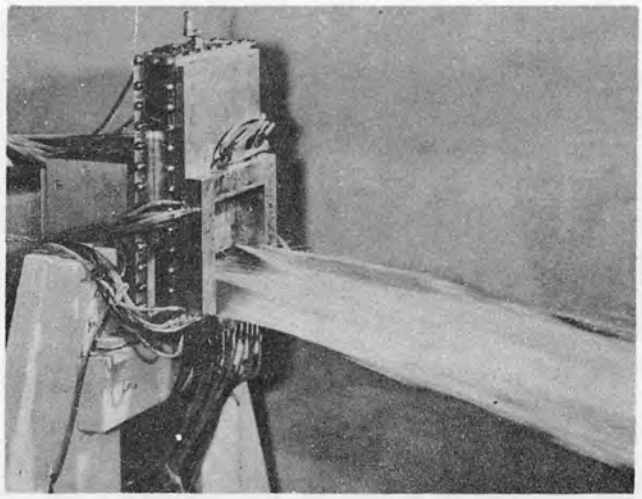
1 : 19 Scale Model



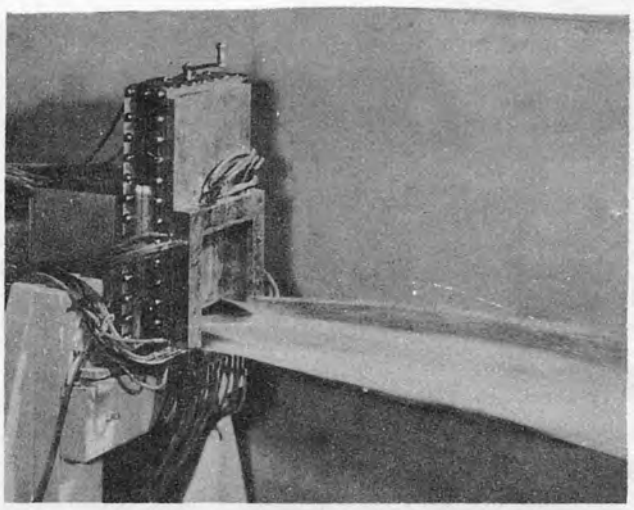
A. Full open, 8270 cfs



B. 60% open, 4030 cfs

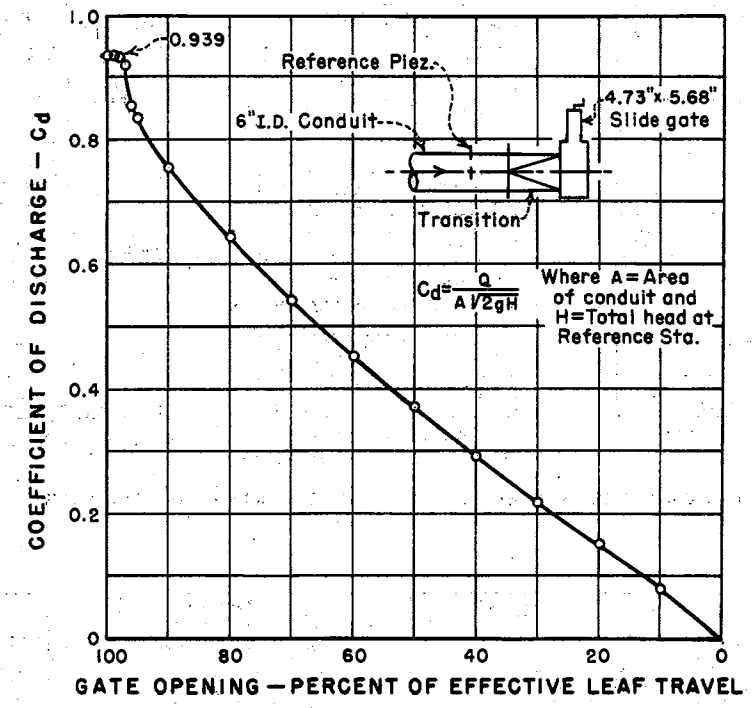


C. 40% open, 2610 cfs

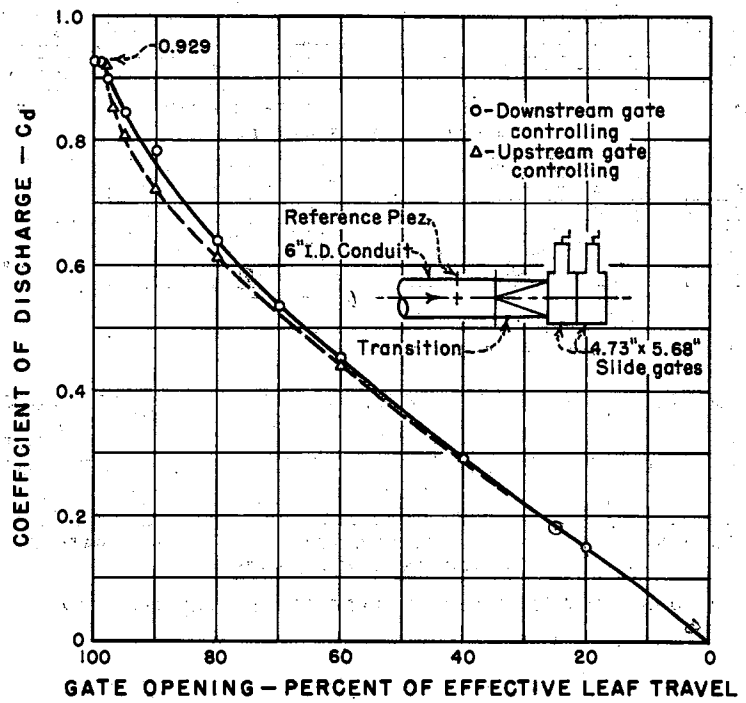


D. 20% open, 1360 cfs

PALISADES REGULATING SLIDE GATE
Recommended Design, 7' - 6" x 9' - 0" Downstream Seal Gate
Flow conditions for 1:19 scale model at an
equivalent head of 240 feet



A. — SINGLE GATE



B. — TANDEM GATES

PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6" x 9'-0" DOWNSTREAM SEAL GATE

COEFFICIENT OF DISCHARGE VERSUS GATE OPENING — FREE DISCHARGE

Data from 1:19 Scale Model

FIGURE 21
REPORT HYD. 387

STA.	PIEZOMETERS A	B	C	D	E	F
1	16.61	14.74	12.09	8.72	7.23	0.47
2	17.73	15.86	12.84	10.22	6.48	1.22
3	11.35	10.79	10.22	9.47	7.99	5.33
4	14.96	14.36	11.72	9.85	6.48	2.73
5	16.61	14.74	11.35	8.72	5.33	0.84
6	13.34	11.28	6.77	2.84	0.20	-3.17
7	4.71	5.46	4.34	0.38	-0.18	-4.30
8	21.00	14.28	8.23	5.79	1.09	-3.03

GATE SLOT	⑨	⑩	⑪	⑫
	7.89	10.08	9.13	12.22

GATE 100 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	18.83	16.59	13.60	10.24	6.87	2.04
2	19.21	17.33	13.60	10.99	7.26	1.65
3	12.10	11.73	10.99	10.24	8.37	5.77
4	16.59	15.85	12.86	10.24	7.26	3.51
5	18.01	15.77	12.41	9.78	7.10	1.58
6	-18.65	12.33	8.96	4.50	1.80	-1.85
7	*-38.82	-1.48	5.99	2.63	1.50	-2.60
8	5.77	8.00	7.26	5.77	1.65	-2.08

GATE SLOT	⑨	⑩	⑪	⑫
	6.73	8.31	7.92	11.96

GATE 99 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	16.80	15.79	13.95	10.35	6.94	1.90
2	17.48	16.60	13.95	11.29	7.59	1.70
3	14.97	13.95	12.51	11.01	9.32	6.80
4	16.80	15.98	13.54	11.09	7.41	3.61
5	16.69	17.62	14.21	11.21	7.25	2.17
6	-1.57	-1.40	-1.45	-0.77	-0.17	-0.23
7	-1.12	-0.44	-1.32	-0.71	-0.77	0.32
8	17.01	9.18	5.38	5.58	3.61	0.01

GATE SLOT	⑨	⑩	⑪	⑫
	15.69	15.84	15.71	16.56

GATE 98 % OPEN

NO AIR ADMITTED THROUGH VENTS

STA.	PIEZOMETERS A	B	C	D	E	F
6	16.36	14.28	8.60	4.38	1.20	-2.40
7	-3.25	1.40	2.00	4.55	8.16	7.11

GATE 100 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
6	-5.50	-5.30	-2.75	-0.77	0.05	-1.95
7	-3.11	-3.75	-4.90	-5.30	-4.75	-5.70

GATE 99 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
6	-0.05	-0.50	-0.50	-0.30	0.30	0.15
7	2.80	-0.06	-0.20	-0.30	0.30	-0.06

GATE 98 % OPEN

AIR ADMITTED THROUGH VENTS

A - DOWNSTREAM (REGULATING) GATE CONTROLLING THE FLOW

STA.	PIEZOMETERS A	B	C	D	E	F
1	19.79	17.90	15.20	13.07	11.03	8.96
2	20.69	18.41	15.49	14.44	11.75	10.50
3	12.80	12.98	12.37	13.19	11.11	12.80
4	16.95	16.31	14.65	13.83	11.53	7.99
5	19.19	17.53	14.40	12.94	10.02	7.13
6	19.15	14.57	10.21	6.65	3.53	0.20
7	11.44	11.67	9.37	5.20	3.12	0.83
8	24.68	21.74	11.75	8.83	3.10	-2.20

GATE SLOT	⑨	⑩	⑪	⑫
	6.65	7.95	11.24	7.54

GATE 100 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	20.93	18.65	15.53	13.23	11.37	8.88
2	22.06	19.14	15.82	14.77	11.86	10.63
3	13.11	13.32	12.49	13.32	11.24	12.70
4	18.10	17.07	15.20	14.16	11.65	8.12
5	20.35	18.28	14.73	13.07	10.16	7.26
6	-15.66	17.40	12.41	7.84	4.51	1.19
7	-17.53	14.49	12.62	7.20	4.51	0.14
8	9.58	11.24	9.99	7.92	2.93	-1.85

GATE SLOT	⑨	⑩	⑪	⑫
	5.13	6.01	10.11	6.22

GATE 99 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	21.84	19.37	15.86	13.19	10.93	8.66
2	22.33	19.46	16.15	14.72	11.83	10.38
3	12.87	12.87	12.23	12.87	11.01	12.44
4	18.01	17.19	14.93	13.89	11.21	7.91
5	21.07	18.80	15.09	13.23	10.34	7.05
6	*-67.39	*-27.81	10.93	9.48	6.40	2.89
7	*-68.41	*-48.84	1.44	8.66	5.97	2.48
8	*-35.77	-12.49	2.97	5.03	2.56	-0.94

GATE SLOT	⑨	⑩	⑪	⑫
	3.09	4.16	9.07	4.99

GATE 98 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	36.21	34.52	31.69	28.69	25.86	22.66
2	37.41	35.53	32.15	30.27	26.49	24.05
3	32.15	31.57	29.69	29.13	25.75	26.32
4	35.53	34.60	30.83	29.88	26.32	21.60
5	37.20	35.30	31.36	28.72	25.14	20.44
6	The flow is not in contact with the roof					
7						
8	13.52	5.61	4.19	1.84	-0.42	-0.99

GATE SLOT	⑨	⑩	⑪	⑫
	30.18	30.22	33.38	31.54

GATE 97 % OPEN

NO AIR ADMITTED THROUGH VENTS

STA.	PIEZOMETERS A	B	C	D	E	F
6	18.16	16.50	9.48	5.60	1.71	-3.03
7	11.70	11.50	6.90	3.80	1.94	-3.50
8	24.88	17.17	10.91	6.36	1.39	-4.85
13	13.30	9.80	6.46	3.74	0.84	-1.85
14	-3.68					
15	-0.30					

GATE 100 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
6	-8.70	-10.30	-8.10	-6.20	-5.40	-7.70
7	-9.70	-10.60	-10.35	-11.50	-11.45	-11.50
8	5.60	0.40	-2.41	-3.50	-6.10	-10.60
13	13.10	9.42	6.30	3.60	0.50	-2.20
14	-7.80					
15	-3.30					

GATE 99 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
6	-3.10	-4.75	-5.60	-4.65	-4.70	-4.70
7	6.50	6.10	6.50	6.10	5.90	-2.40
8	12.30	5.60	1.60	0.01	-0.70	-4.08
13	16.60	12.10	7.80	4.65	3.11	-1.60
14	-5.50					
15	-4.40					

GATE 98 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
6	The flow is not in contact with the roof					
7						
13	11.80	16.00	9.10	6.00	4.10	-0.40

GATE 97 % OPEN

GATE 20 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	93.2	75.3	32.0	21.9	12.1	6.0
2	99.8	79.1	46.7	28.5	15.6	9.1
3	83.8	65.6	38.4	22.9	10.3	9.1
4	96.3	77.1	47.6	28.9	14.1	4.3

GATE 15% OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	72.4	54.2	25.0	12.4	10.4	12.8
2	82.5	59.6	29.4	18.1	12.2	16.4
3	72.6	51.2	22.8	12.2	4.3	6.9
4	81.2	55.9	25.8	14.6	7.0	1.0

GATE 10 % OPEN

STA.	PIEZOMETERS A	B	C	D	E	F
1	72.2	62.6	53.0	51.5	51.2	52.1
2	88.6	70.4	55.7	54.2	52.3	55.3
3	84.6	65.4	50.8	49.4	46.3	49.2
4	86.3	64.8	53.4	52.3	50.0	48.7

GATE 5% OPEN

AIR ADMITTED THROUGH VENTS

B - UPSTREAM (EMERGENCY) GATE CONTROLLING THE FLOW

Refer to Figures 2 and 3 for piezometer locations.

Pressures given in feet of water, prototype, for a total head of 240 feet above conduit ℄.

* - Scaled-up model values. These pressures would not be reached in prototype structure because cavitation would occur at approximately -30 feet and there would be no further pressure reduction.

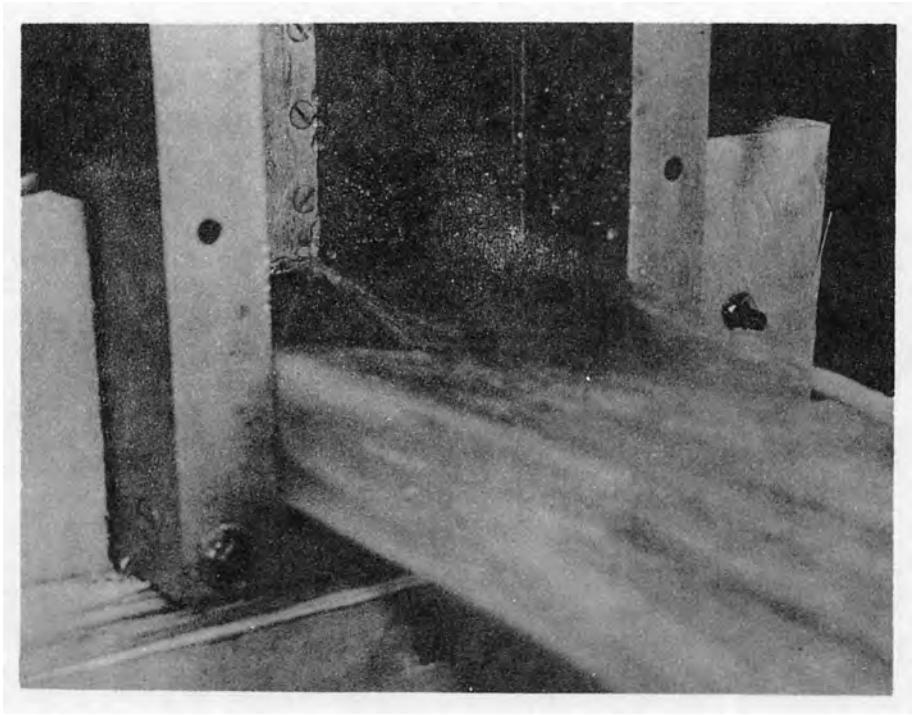
PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6" x 9'-0" DOWNSTREAM SEAL GATE

PIEZOMETRIC PRESSURES WITH DOWNSTREAM OR UPSTREAM GATE CONTROLLING FLOW

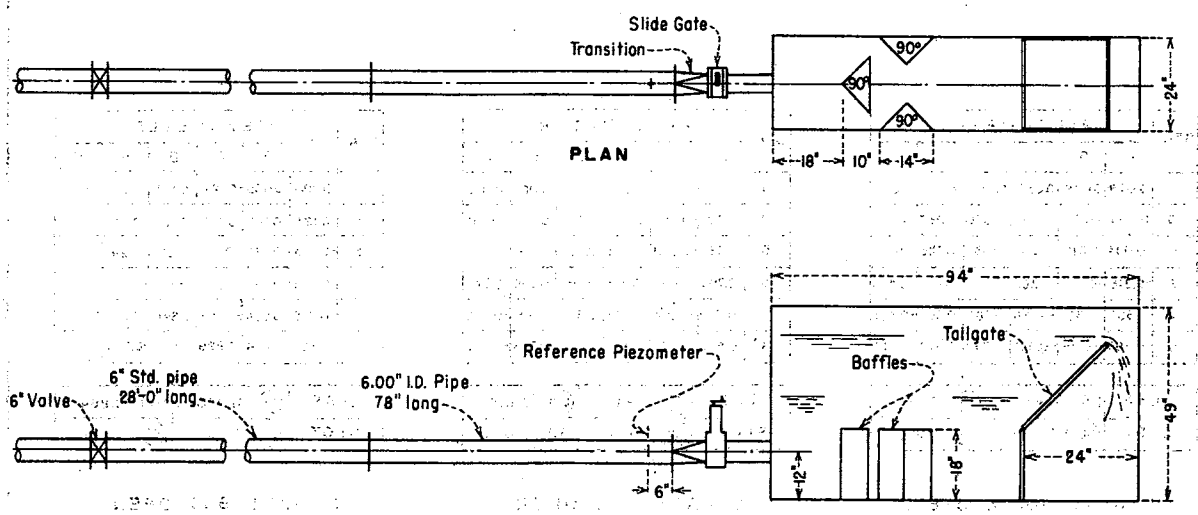
Data from 1 : 19 Scale Model

348

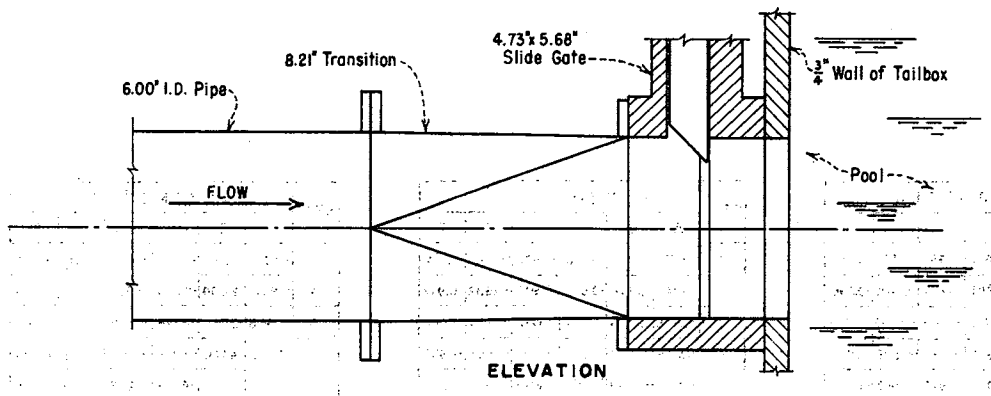


Gate 20% open, 1360 cfs

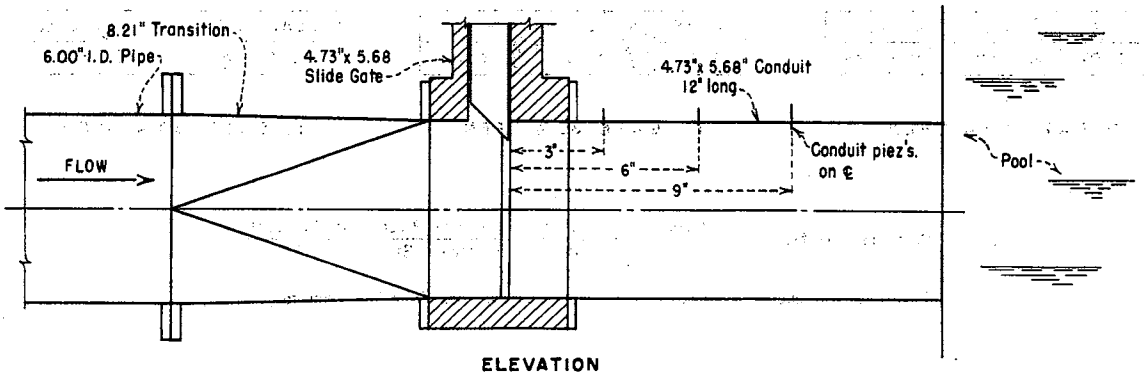
PALISADES REGULATING SLIDE GATES
Recommended Design, 7' - 6" x 9' - 0" Downstream Seal Gate
Flow conditions for 1:19 scale model with gates in
tandem and upstream gate controlling at
equivalent head of 240 feet



A. SCHEMATIC VIEW OF TEST SET-UP



B. FLOW PASSAGE WITH GATE DISCHARGING INTO POOL



C. FLOW PASSAGE WITH GATE DISCHARGING INTO CONDUIT

PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6" x 9'-0" DOWNSTREAM SEAL GATE

1:19 SCALE MODEL ARRANGEMENT FOR SUBMERGED-FLOW TESTS

STA.	PIEZOMETER					
	A	B	C	D	E	F
1	0.078	0.078	0.053	0.044	0.026	0
3	0.053	0.053	0.061	0.070	0.087	0.114
5	0.044	0.018	-0.009	-0.035	-0.035	-0.078
6	-0.316	-0.333	-0.368	—	-0.404	-0.430
7	-0.351	-0.351	-0.368	-0.368	-0.395	-0.421
8	-0.298	-0.316	-0.351	-0.342	-0.377	-0.412

LEAF	(19) -0.439	(20) -0.342
SLOT	(52) -0.026	(53) 0

A. GATE 100 % OPEN

STA.	PIEZOMETER					
	A	B	C	D	E	F
1	0	-0.005	-0.022	-0.038	-0.060	-0.082
3	-0.033	-0.027	-0.022	-0.016	-0.005	+0.033
5	-0.027	-0.049	-0.055	-0.093	-0.124	-0.165
6	-0.703	-0.407	-0.313	—	-0.346	-0.374
7	-0.709	-0.604	-0.363	-0.308	-0.319	-0.346
8	-0.522	-0.401	-0.335	-0.319	-0.346	-0.374

LEAF	(19) -0.846	(20) -0.610
SLOT	(52) -0.110	(53) -0.082

B. GATE 98% OPEN

STA.	PIEZOMETER					
	A	B	C	D	E	F
1	-0.090	-0.095	-0.121	-0.141	-0.171	-0.201
3	-0.121	-0.121	-0.116	-0.121	-0.100	-0.025
5	-0.115	-0.141	-0.171	-0.201	-0.241	-0.296
6	-0.869	-0.889	-0.869	—	-0.603	-0.523
7	-0.789	-0.804	-0.844	-0.844	-0.779	-0.663
8	-0.824	-0.834	-0.829	-0.668	-0.578	-0.513

LEAF	(19) -0.950	(20) -0.864
SLOT	(52) -0.196	(53) -0.161

C. GATE 95% OPEN

STA.	PIEZOMETER					
	A	B	C	D	E	F
1	-0.355	-0.360	-0.411	-0.467	-0.538	-0.619
3	-0.350	-0.360	-0.381	-0.411	-0.406	-0.396
5	-0.381	-0.401	-0.452	-0.518	-0.599	-0.716
6	-0.888	-0.904	-0.929	—	-0.929	-0.898
7	-0.939	-0.954	-0.959	-0.970	-0.985	-1.000
8	-0.919	-0.919	-0.934	-0.959	-1.005	-1.015

LEAF	(19) -0.954	(20) -0.872
SLOT	(52) -0.330	(53) -0.345

D. GATE 90% OPEN

STA.	PIEZOMETER					
	A	B	C	D	E	F
1	-0.732	-0.758	-0.858	-0.979	-1.116	-1.274
3	-0.742	-0.774	-0.832	-0.911	-0.932	-0.947
5	-0.726	-0.784	-0.911	-1.042	-1.184	-1.400
6	-1.626	-1.632	-1.637	—	-1.653	-1.653
7	-1.626	-1.642	-1.653	-1.658	-1.663	-1.668
8	-1.621	-1.621	-1.632	-1.637	-1.668	-1.668

LEAF	(19) -1.610	(20) -1.579
SLOT	(52) -0.716	(53) -0.716

E. GATE 80% OPEN

STA.	PIEZOMETER					
	A	B	C	D	E	F
1	-1.824	-1.936	-2.288	-2.624	-3.008	-3.408
3	-1.968	-2.064	-2.264	-2.504	-2.608	-2.696
5	-1.808	-2.016	-2.376	-2.712	-3.040	-3.640
6	-4.216	-4.200	-4.216	—	-4.256	-4.304
7	-4.216	-4.208	-4.192	-4.232	-4.216	-4.256
8	-4.200	-4.200	-4.216	-4.232	-4.240	-4.240

LEAF	(19) -4.100	(20) -4.050
SLOT	(52) -2.040	(53) -1.824

F. GATE 60% OPEN

$$\text{Pressure Coefficient} = \frac{\text{Piezometer Pressure} - \text{Reference Piezometer Pressure}}{\text{Velocity Head at Reference Station}}$$

Reference piezometer in 6-inch I.D. pipe 1 diameter upstream from transition to gate.

PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6"x 9'-0" DOWNSTREAM SEAL GATE

PRESSURE COEFFICIENTS FOR DISCHARGING SUBMERGED DIRECTLY INTO POOL—NO AIR VENTS

Data from 1:19 Scale Model

STA.	PIEZOMETER A	B	C	D	E	F
1	-0.092	-0.100	-0.129	-0.128	-0.150	-0.176
2	-0.124	-0.122	-0.133	-0.083	-0.113	-0.113
5	-0.083	-0.094	-0.109	-0.118	-0.122	-0.128
6	-0.159	-0.133	-0.122	-0.205	-0.209	-0.227
7	-0.166	-0.163	-0.181	-0.224	-0.218	-0.233
8	-0.103	-0.135	-0.165	-0.198	-0.220	-0.250

CONDUIT	55 -0.253	56 -0.229	57 -0.236
LEAF	19 -0.240	20 -0.113	
SLOT	52 -0.124	53 -0.161	

A. GATE 100 % OPEN

STA.	PIEZOMETER A	B	C	D	E	F
1	-0.094	-0.105	-0.137	-0.135	-0.162	-0.188
3	-0.137	-0.135	-0.149	-0.098	-0.127	-0.127
5	-0.089	-0.103	-0.118	-0.133	-0.138	-0.140
6	-0.166	-0.347	-0.603	-0.190	-0.205	-0.223
7	-0.603	-0.504	-0.247	-0.210	-0.208	-0.223
8	-0.432	-0.306	-0.221	-0.220	-0.231	-0.253

CONDUIT	55 -0.248	56 -0.231	57 -0.238
LEAF	19 -0.760	20 -0.507	
SLOT	52 -0.140	53 -0.173	

B. GATE 98 % OPEN

STA.	PIEZOMETER A	B	C	D	E	F
1	-0.168	-0.182	-0.228	-0.230	-0.262	-0.293
3	-0.221	-0.221	-0.238	-0.182	-0.217	-0.219
5	-0.156	-0.179	-0.203	-0.223	-0.228	-0.236
6	-0.950	-0.954	-0.932	-0.891	-0.738	-0.547
7	-0.830	-0.851	-0.878	-0.902	-0.886	-0.799
8	-0.871	-0.897	-0.923	-0.877	-0.737	-0.587

CONDUIT	55 -0.266	56 -0.244	57 -0.264
LEAF	19 -0.989	20 -0.733	
SLOT	52 -0.223	53 -0.291	

C. GATE 95 % OPEN

STA.	PIEZOMETER A	B	C	D	E	F
1	-0.298	-0.318	-0.379	-0.391	-0.440	-0.485
3	-0.353	-0.357	-0.387	-0.329	-0.385	-0.393
5	-0.290	-0.316	-0.337	-0.391	-0.407	-0.424
6	-1.110	-1.079	-1.063	-1.138	-1.118	-1.103
7	-1.061	-1.067	-1.075	-1.101	-1.122	-1.138
8	-1.037	-1.047	-1.097	-1.110	-1.108	-1.108

CONDUIT	55 -0.990	56 -0.384	57 -0.337
LEAF	19 -1.119	20 -1.102	
SLOT	52 -0.345	53 -0.400	

D. GATE 90 % OPEN

STA.	PIEZOMETER A	B	C	D	E	F
1	-0.651	-0.690	-0.807	-0.857	-0.974	-1.078
3	-0.729	-0.753	-0.828	-0.776	-0.891	-0.938
5	-0.628	-0.688	-0.766	-0.841	-0.911	-0.971
6	-1.742	-1.721	-1.716	-1.763	-1.768	-1.776
7	-1.703	-1.755	-1.766	-1.769	-1.841	-1.800
8	-1.708	-1.714	-1.724	-1.742	-1.760	-1.760

CONDUIT	55 -1.809	56 -1.720	57 -1.140
LEAF	19 -1.738	20 -1.717	
SLOT	52 -0.674	53 -0.768	

E. GATE 80 % OPEN

STA.	PIEZOMETER A	B	C	D	E	F
1	-1.614	-1.754	-2.084	-2.242	-2.586	-2.877
3	-1.863	-1.961	-2.137	-2.098	-2.418	-2.512
5	-1.579	-1.797	-2.067	-2.330	-2.471	-2.681
6	-4.053	-4.049	-4.046	-4.053	-4.060	-4.067
7	-4.049	-4.060	-4.074	-4.088	-4.249	-4.084
8	-4.042	-4.046	-4.049	-4.042	-4.056	-4.060

CONDUIT	55 -4.340	56 -4.352	57 -4.245
LEAF	19 -4.020	20 -3.975	
SLOT	52 -1.628	53 -1.986	

F. GATE 60 % OPEN

$$\text{Pressure Coefficient} = \frac{\text{Piezometer Pressure} - \text{Reference Piezometer Pressure}}{\text{Velocity Head at Reference Station}}$$

Reference piezometer in 6-inch I.D. pipe 1 diameter upstream from transition to gate.

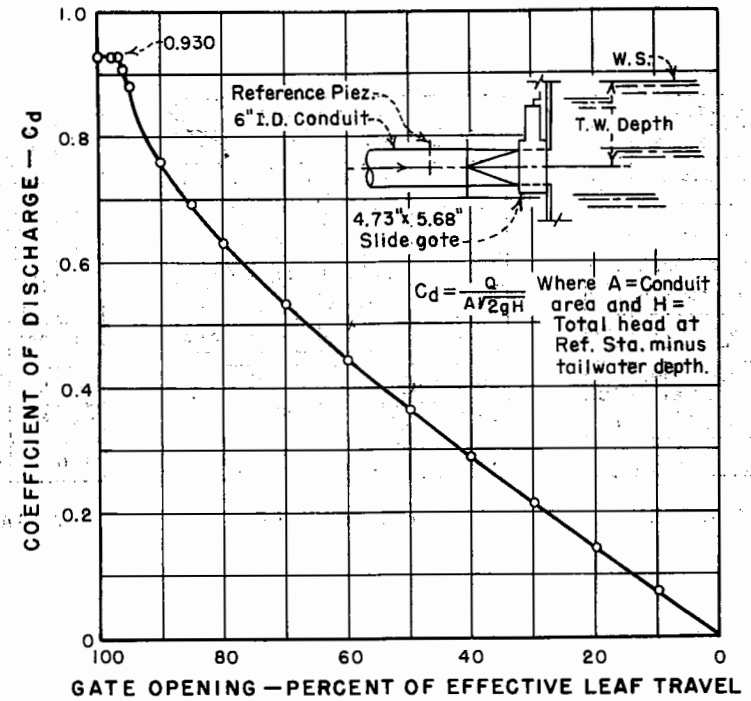
PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6" x 9'-0" DOWNSTREAM SEAL GATE

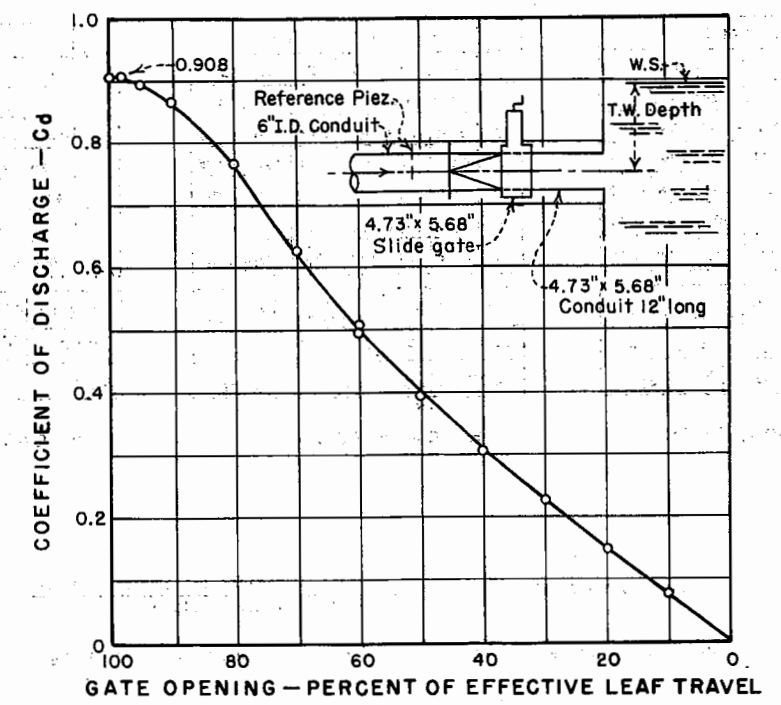
PRESSURE COEFFICIENTS FOR DISCHARGING SUBMERGED INTO A SHORT RECTANGULAR CONDUIT

NO AIR VENTS

Data from 1:19 Scale Model



A. — DISCHARGE DIRECTLY INTO POOL



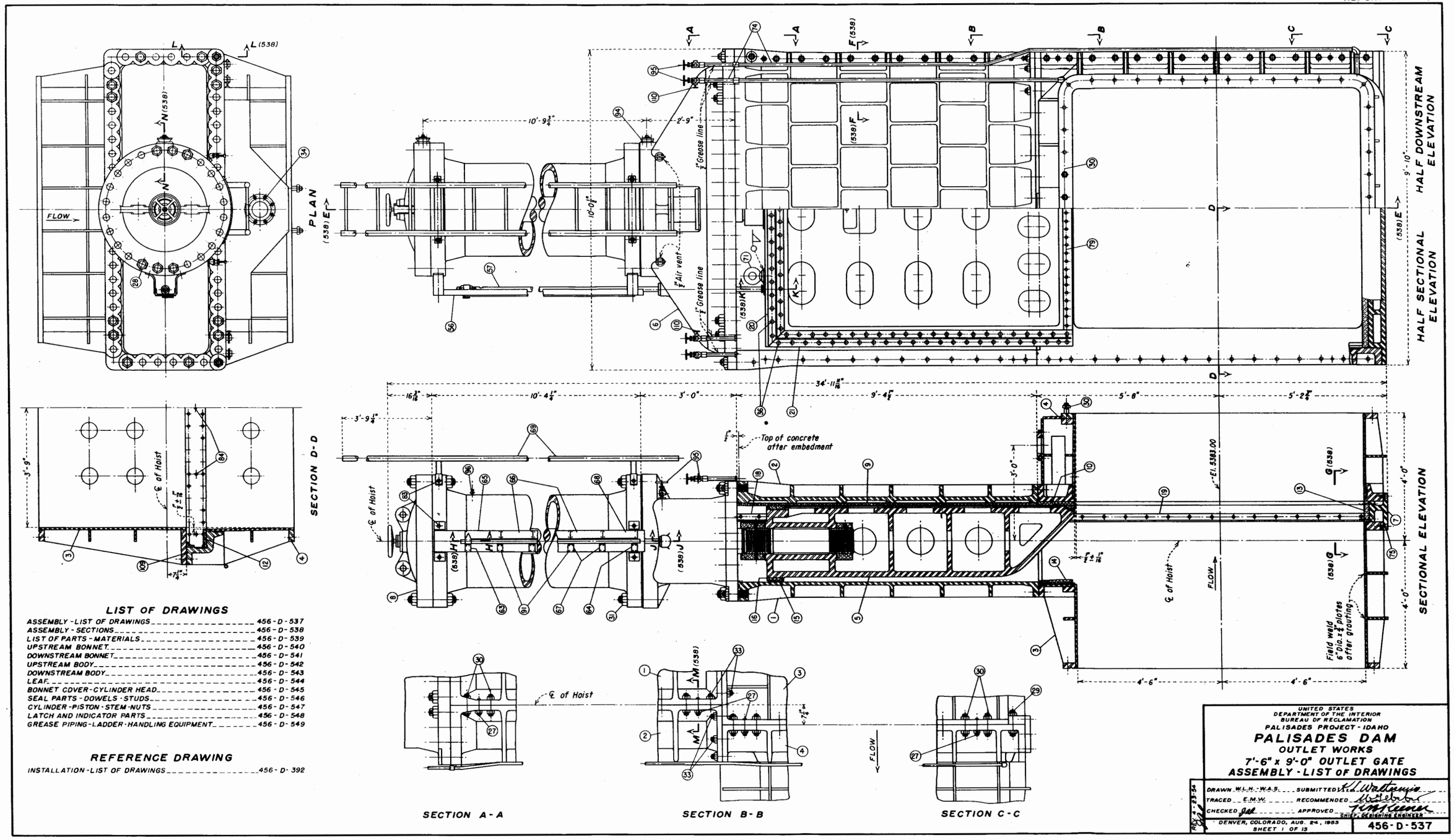
B. — DISCHARGE INTO SUBMERGED CONDUIT

PALISADES REGULATING SLIDE GATE

RECOMMENDED DESIGN 7'-6" x 9'-0" DOWNSTREAM SEAL GATE

COEFFICIENT OF DISCHARGE VERSUS GATE OPENING — SUBMERGED FLOW

Data from 1:19 Scale Model

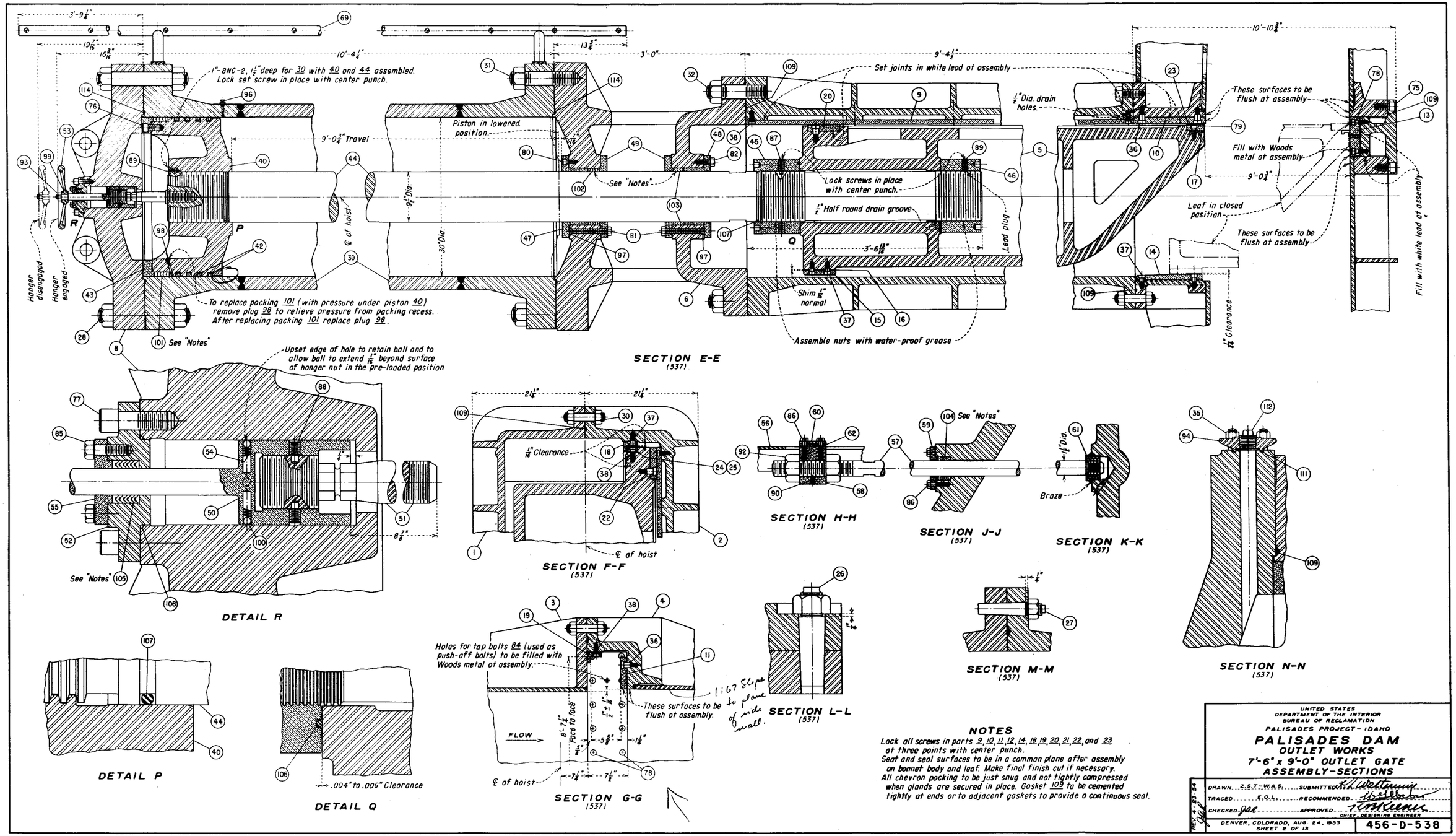


LIST OF DRAWINGS

ASSEMBLY - LIST OF DRAWINGS	456-D-537
ASSEMBLY - SECTIONS	456-D-538
LIST OF PARTS - MATERIALS	456-D-539
UPSTREAM BONNET	456-D-540
DOWNSTREAM BONNET	456-D-541
UPSTREAM BODY	456-D-542
DOWNSTREAM BODY	456-D-543
LEAF	456-D-544
BONNET COVER-CYLINDER HEAD	456-D-545
SEAL PARTS - DOWELS - STUDS	456-D-546
CYLINDER - PISTON - STEM - NUTS	456-D-547
LATCH AND INDICATOR PARTS	456-D-548
GREASE PIPING - LADDER - HANDLING EQUIPMENT	456-D-549

REFERENCE DRAWING

INSTALLATION - LIST OF DRAWINGS	456-D-392



NOTES

Lock all screws in parts 9, 10, 11, 12, 14, 18, 19, 20, 21, 22, and 23 at three points with center punch.
Seat and seal surfaces to be in a common plane after assembly on bonnet body and leaf. Make final finish cut if necessary.
All chevron packing to be just snug and not tightly compressed when glands are secured in place. Gasket 109 to be cemented tightly at ends or to adjacent gaskets to provide a continuous seal.

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

PALISADES DAM
OUTLET WORKS
7'-6" x 9'-0" OUTLET GATE
ASSEMBLY-SECTIONS

DRAWN	E.S.T.-W.A.S.	SUBMITTED	
TRACED	E.O.L.	RECOMMENDED	
CHECKED		APPROVED	CHIEF, DESIGNING ENGINEER

DENVER, COLORADO, AUG. 24, 1953
SHEET 2 OF 13

456-D-538

REV. 4-23-54