UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC LABORATORY TESTS OF SEALS FOR HIGH-HEAD COASTER AND FIXED WHEEL STRUCTURAL STEEL GATES

Hydraulic Laboratory Report No. Hyd.-311

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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Laboratory Report No. Hyd-311
Hydraulic Laboratory
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Subject: Hydraulic Laboratory tests of seals for high-head*, coaster and fixed wheel structural steel gates.

PURPOSE

(a) Determine the manner of the failures of the bottom "music-note" - type rubber seal on high head coaster and fixed-wheel gates and

(b) To develop a satisfactory seal.

CONCLUSIONS

1. The hollow bulb music-note seal (Figure 2A) with or without a brass bulb shield, cannot structurally withstand the forces to which subjected during emergency closure of these gates at heads as low as 40 feet (Figure 12). During closure under emergency conditions, the bulb of the bottom seal takes an elliptical shape due to the water forces and is pinched in a scissor action, between the seal seat on the face of the dam and seal stem clamp plate on the gate, thus pulling the seal off the gate (Figures 5 and 6). The seal behavior is unsatisfactory with or without a seal bulb retraction system (Figures 17 and 18A).

2. The solid bulb music-note seal without the brass shield shown on Figure 2B is somewhat better than the hollow bulb seal, but it is also too easily deformed by the water forces (Figure 14). The seal bulb is pinched at heads as low as 60 feet.

3. The solid bulb music-note seal with a 90° brass shield on the bulb is the best design of the music-note type of seal tested (Figure 2B).

4. The solid bulb music-note seal with a brass shield on the outside of the seal stem which continues around the bulb (Figure 16) makes the seal too rigid, as the seal bulb did not reach the seat at the larger seal-to-seat gaps, 1/8 to 1/4 inch. When the seal stem bends, the brass shield tends to stay bent (Figure 16B). Further, the seals tested had very poor rubber-to-brass bond and bending often caused separation.

5. The principal undesirable feature of the solid bulb music-note seal is that the single stem does not provide adequate position control of the bulb which "hinges" freely on the single stem.

*Arbitrarily defined as 100 feet or more.

6. The double-stem type of seal (Figure 24) is superior to the music-note type of seal. Two stems provide adequate position control of the seal bulb. However, if a corner exists at the top of the seat bevel, this seal without a 180° brass shield is unsatisfactory because at zero seal-to-seat gap, 195-foot head, and the bulb extended continuously (no retraction), the bulb is pinched (Figure 26A).

7. Brass seal stem reinforcing plates can be molded satisfactorily into the double-steam seal (Figures 23 and 29) to increase the seal's resistance from being pulled off the gate, but the resulting seal stem is too stiff for acceptable seal operation; i. e., retraction was poor and the bulb did not seal a 1/4-inch seal-to-seat gap at 195-foot head.

8. For both the solid music-note and the double-stem seal a 1/16-inch brass shield bonded 180° around the seal bulb is desirable to maintain the seal bulb shape during gate closure, to aid the seal to slide past the upper corner (if present) of the seat bevel (Figure 3), and to reduce the gate's frictional force against the seat.

9. Based on visual observations, a slotted, 180° brass shield bonded to the double-stem seal is as an effective seal as one without the shield (Figure 27, View x-x).

10. The double-stem seal assembly, Design No. 1 shown in Figures 39 and 40A, which uses no stem-attaching screws, is unsatisfactory because the seal-to-seat gap that can be sealed is limited and during retraction the seal bulb section twists noticeably and the lower stem of the seal buckles (Figures 40B and 41).

11. The double-stem seal assembly with molded circular sections on the stem ends and which uses no stem-attaching screws, Design No. 2 shown in Figure 42, is the most promising of all seals tested. It sealed a zero to 1/4-inch seal-to-seat gap at 195-foot head, with or without a 180° brass bulb shield, and with or without seal bulb retraction provision in the gate; i.e., without a brass shield, the seal bulb did not get pinched as did the double-stem seal referred to in Conclusion 6.

12. Automatic retraction and extension of the seal bulb, using existing gate parts for hydraulic control points, was satisfactorily achieved in the laboratory for both the solid music-note and double-stem bottom seals (Figures 20 and 38).

13. An adaption of the double-stem seal to function similar to the music-note type seal provides a promising seal for the bottom of the Shasta Dam penstock and river outlet gates (Figure 34). The seal of conclusion 11 is preferable, but it can not be installed for the bottom seal of the Shasta gate because of space limitations on the gate.

RECOMMENDATIONS

1. Smoothly blend the seal-seat bevel with the surface of the penstock or river outlet entrance on future designs to prevent sharp edges or corners from catching-hold of the seal bulb as in the case of the design shown in Figure 3.

2. Field test the double-stem seal with the molded circular sections on the stem ends which uses no stem-attaching screws, Design No. 2 (Figure 44).

3. Field test at 200-foot head the double-stem seal with automatic retraction and extension of the seal bulb (Figure 38).

4. Install for field tests the adaptation of the double-stem seal which functions as music-note seal on one Shasta gate (Figure 34).

ACKNOWLEDGEMENT

This study was conducted jointly by engineers from the Mechanical Division and the Hydraulic Laboratory of the Research and Geology Division.

INTRODUCTION

The seals discussed in this report apply specifically to high-head gates for penstock or river outlet entrances such as that shown in Figure 1. High head is arbitrarily defined here as a hydrostatic head of 100 feet or more. These gates are normally operated with balanced water pressure across them but during emergency closure have reservoir water pressure on the upstream side and a much lower pressure (approximately atmospheric) on the downstream side as noted on Figure 3. Seals are provided to prevent leakage and permit unwatering of the downstream conduit for inspection or repair. In general, the music-note type of gate seal (Figure 2) on high-head structural steel gates has given unsatisfactory service at heads of 200 to 300 feet when these gates are closed under unbalanced pressures. The bottom seals have been the most troublesome during emergency closure of the gates.

The top seal is the next most troublesome. No failures have occurred in the side seals (Figure 4) where the side seal seats extend one gate height above the conduit opening. Penstock gates have been raised, and the bottom or top seal has been found torn from the gate or part of the seal missing (Figures 5 and 6). A drop-tight seal is not required. It is impracticable to obtain and unwatering pumps are included in the penstock and tunnel equipment. Seal leakages as high as 4,000 gallons per minute (about 9 cfs) have occurred in the field, and maintenance work was not possible on structures and equipment downstream from the closed gate. The maximum permissible gate seal leakage is about 250 gallons per minute (0.56 cfs). This gate seal problem has not received particular attention in the past due to the small number of high head gates and the infrequency of emergency gate closures.

Because of the difficulties numerated above and the increased number of high head gate installations in recent years, the Mechanical Division requested that the Research and Geology Division make the necessary tests to determine the manner of the music-note seal failures. This seal study is concerned with the mechanical behavior of the seal and its geometric shape, and not the improvement in the materials of the sealing surfaces, such as the rubber compound. A seal assembly is not considered acceptable unless it will seal over a zero to 1/4-inch seal-to-seat gap range (Dimension G, Figures 20 and 38). All metal shields, bonded to the seal bulb, used in these studies were made of 1/16-inch thick, half-hard, yellow brass. Pertinent information on penstock gates projects that were of immediate concern at that time are shown in the table below:

Dam	Grand Coulee	Hungry Horse	Canyon Ferry	Falcon	Shasta
Location	Washington	Montana	Montana	Texas	Calif.
Size of gates	15x29.65 ft	13.5x18.93 ft	12.78x21.78 ft	10.75x20.56ft	15x19.05ft
Maximum head	264 ft	265 ft	121 ft	93 ft	260 ft
Actuating valve and piping equip. built into gate to extend and retract seal	Yes	No	No	No	Yes
Gate weight will overcome rubber seal-to-metal seat friction	Probably	No	Yes	No	Probably

When the gate weight is insufficient to fully lower the gate due to the rubber seal-to-metal seat friction, one of two things must be done:

(a) Build into the gate an actuating valve and piping to retract the seal bulb so that it does not rub on the seat during opening and closing of the gate. The principal objections to this are that the gate is further complicated mechanically and additional equipment is required.

(b) Reduce the coefficient of friction between the sealing surfaces. This may be done by vulcanizing a brass shield (usually 1/16-inch thick) to the seal bulb which gives a metal-to-metal seal surface. The principal objections to this scheme are that sealing is impaired somewhat and that the seal manufacturers do not obtain a durable bond between the rubber and brass. A loose metal sheath (bronze or steel tubing, Figure 7) has been installed on the music-note seal bulb in field installations, but it does not give satisfactory service.

The Gates Rubber Company of Denver, Colorado, supplied all of the experimental test seals, the majority free of charge. The exceptions were the seals shown in Figures 40A and 42, which required completely new molds. The physical characteristics of the rubber stock, Gates Rubber Compound No. 1564, used in all the seal test samples is given below:

Tensile strength, psi, min	3,500
Elongation at break, percent, min	500
Shore durometer (Type A)	60 to 70
Specific gravity	1.14
Absorption of water, by weight, percent, max	3.7
Compression set (constant deflection) percent of original deflection, max	23
Tensile strength after oxygen bomb aging (48 hours, 70° C, 300 psi), percent of tensile strength before aging, min	80

METHODS OF OPERATING THE SEAL BULB

Continuous Seal-bulb Extension

This method of extending the seal bulb to the seat on the dam is the simplest method used. The reservoir head is made easily accessible to the region behind the seal bulb, as illustrated for the music-note seal in Figure 4. Holes of no fixed size are drilled in the angle iron guard adjacent to the seal to assure reservoir head on the gate side of, or behind, the seal bulb. For the double-stem seal, water passages can be provided in the steel members around the outer part of the gate to route reservoir head to the region on the gate side of the seal bulb. The bulb is extended during all gate movement, and this method of seal bulb operation is called continuous bulb extension. Bulb retraction to break the seal and completely remove the seal-to-seat frictional drag is not intended. This method of bulb operation in unsatisfactory with the music-note seal as described in the MUSIC-NOTE SEAL DESIGNS section of this report. The double-stem seal is better adapted to this method of extending the seal bulb.

Actuating Valve and Piping for Retraction and Extension of the Seal Bulb

A drawing showing one type of valve and piping needed for this method of retraction and extension is shown in Figure 8. Briefly, this method is as follows: As the gate approaches the outlet entrance, the cavity behind the bulb is drained by passages to the downstream side of the gate where low pressure exists, and it is intended that the seal bulb remain retracted with no rubbing on the seal seat while the gate is in motion. After the gate is closed and resting on the gate stops, the gate stem is free to lower further. This additional gate stem travel operates the seal actuating valve which closes the above-mentioned drain and routes reservoir pressure to the cavity behind the bulb, thus extending it to the seal seat. When it is desired to open the gate, the initial movement of the gate stem again operates the actuating valve and the cavity behind the bulb is drained of water to the downstream side of the gate before the gate moves upward. Thus, the gate seal is broken before any upward gate movement. This, of course, reduces the gate hoisting requirements over the method where the reservoir head is applied to the seal continuously. On gates under high head, retraction is often necessary to fully close the gate if the gate weight is insufficient to overcome the frictional force of the gate pressed against the dam.

Automatic Retraction and Extension of the Seal Bulb

This method of retracting and extending the seal bulb has heretofore been undeveloped. The operation for two types of seals is as follows:

Music-note seal. Automatic retraction and extension of the bulb is feasible only on the bottom seal of the gate. The top and two side seals are subject to reservoir head continuously behind the seal bulb. Trouble would not be expected when the bottom seal passes over the top seat because the water flow is from top to bottom as shown in Figure 3. The water flow tends to keep the seal stem straight in this location with no tendency for it to curl around the stem clamp plate. However, as the bottom seal approaches the bottom seat, the water flows from bottom to top (Figure 3) and tends to curl the seal bulb around the stem clamp plate. This is when retraction is required to prevent damage to the seal. Retraction is obtained by dimensioning the lower leg of the angle iron so that it serves as a hydraulic control point (Edge X, Figure 20), thus forming a low-static-pressure, high-velocity region everywhere downstream from the angle iron. This low pressure region exhausts the water behind the seal bulb which retracts the bulb to some mechanical stop, such as the heads of cap screws which could be used to attach the angle iron to the gate. As the gate continues to lower, the seal stem clamp plate approaches the seat tending to throttle the water flow which switches the hydraulic control from the angle iron to the lower downstream edge of the stem clamp plate (Edge Y, Figure 20). When this occurs, the water instantly fills the cavity behind the seal bulb at reservoir head which immediately extends or snaps the bulb to the seal seat. The changeover of control points must be adjusted such that the bulb snaps over to the seat when the gates is about 1 inch from its lowest point of travel (gate stop). It is important that the seal bulb does not snap over to the seat too soon nor fails to snap over at all--the latter condition resulting in no seal. When the gate is to be opened, retraction of the seal bulb is not possible, but this is not serious since these gates are normally opened with balanced water forces; i.e., reservoir head on both sides of the gate. Development details of this method of retraction and extension during gate closure are given subsequently in this report for the bottom music-note seal of the gate.

Double-stem seal. Automatic retraction and extension is applied similarly to the double-stem seal (Figure 38). The main difference is in the arrangement of the lower control point. The lower downstream edge of the lower clamp plate serves as the retraction control point (Edge X, Figure 38). Water passage ports on the lower clamp plate vertical face and near the lower downstream edge permits the low pressure at these ports to exhaust the water behind the seal bulb through drilled passages (Figures 37B and 38). When the hydraulic control shifts to the upper clamp plate (Edge Y, Figure 38) or to the seal bulb, water at reservoir head immediately passes through the same passages to extend or snap the bulb into the seat. The Mechanical Division intended that the water passage would be on the clamp plate for the lower seal only, and that the cavity behind the seal bulb on all four sides would be interconnected. Thus, automatic seal-bulb retraction and extension may be applied to all four sides of the gate with a double-stem seal, whereas it can be applied only to the bottom seal with a music-note seal is used, because, as will be discussed later, a suitable seal or separation cannot be provided between the reservoir water and the cavity behind the seal bulb.

DESCRIPTION OF THE TEST EQUIPMENT

An assembly drawing of the test rig is shown in Figure 9. A detail drawing of the removable penstock entrance section is shown in Figure 10. Photographic views of the rig are shown in Figure 11. The latter figure shows a double-stem seal section in place for testing. The rig windows were 2-inch transparent plastic which were used to observe the seal behavior and to permit photographs. The 1-1/2-inch steel back plate shown in Figure 11B was one piece and each plastic window was two pieces. The larger piece of each window fits into a slot in the steel back plate, and the upstream face of the window was shouldered to fit in the rig frame. This piece of each window was compressed between the rig frame and the steel back plate by means of three 5/8-inch tie bolts outside each window. The bottom face of the larger piece of each window was attached to the rig with four 1/8-inch wood screws to insure a watertight seal at this parting surface. Thus, the windows were free of the downstream movement of the back plate due to water loads (particularly water hammer) which made the window assembly durable. The small piece of each window was attached to the steel back plate with flat head screws. Immediately upstream from the steel back plate were five removable shim plates, varying in thickness from 1/16 to 1/2 inch, to permit adjusting the seal bulb-to-seat gap in 1/16-inch increments. The shims were compressed in place by four 1/2-inch cap screws threaded into the seat plate. The shims were slotted for easy removal by loosening the four cap screws. The test gate was operated by a hydraulic jack which in turn was actuated by a portable electric motor-driven oil pump (Figure 11A). The rig sheet metal hood deflected the water to the laboratory channel below the floor grating. The hood attachment to the rig was arranged for quick removal by loosening four nuts to four steel cable ties. The gate-seal test rig was connected to a 12-inch pipe by circular to rectangular transition.

All seals tested were full size sections, 12 inches long. The maximum head available in the laboratory was 195 feet of water. The simulated reservoir head was read on the large Bourdon gage (Figure 11A) tapped into the 12-inch pipe. The hydraulic jack oil pressure was read on the Bourdon gage above the portable motor-pump assembly. The water pressure behind the seal bulb (extension pressure) was read on a pressure-vacuum Bourdon gage. Seal water leakage was small, not easily determined, and small leakages were not important in these tests. Visual observations of the seal-to-seat leakage sufficed. When the seal sealed, the combined leakages of the seal and the rig (past windows, gate leaf, etc.) was too small to be measured on the 6-inch venturi meter in the water supply piping system. Also, it was impossible to separate the seal leakage from the rig leakage.

MUSIC-NOTE SEAL DESIGNS

Variations of the music-note type seal were made, and tests on these seals are described below. It was desired to use the music-note seal with unaltered geometrical shape in order to reduce seal replacement costs on existing field installations. Unless otherwise stated, the seal stem was compressed .010 to .035-inch with the clamp plate. Sheet metal shims were often necessary to obtain this pinch due to the variations in the seal stem thickness. The outside dimensions of all the music-note seals tested were nominally the same.

Hollow Music-note Seal, Showing Manner of Failure

The initial seal tests were with the hollow music-note type seal without a brass shield on the bulb, Figure 2A, and it was assembled as shown in Figure 9. The horizontal leg of the angle iron beneath the seal bulb had five 27/64-inch water passage holes, drill size for 1/4-inch pipe thread, (about 0.7 square inch of open water passage per linear foot of seal) to supply reservoir head behind the seal bulb for continuous bulb extension operation. Actually the amount of open water passage area per linear foot of seal varies on gates at different projects. The seal-to-seat gap was set at zero inches. In closing the test gate at 40-foot head, the pressure conditions around the seal bulb caused it to bounce against the jet, flattening the seal bulb until it became the hydraulic control, and the seal finally closed as shown in Figure 12A, pinching the seal bulb between the seal seat and seal stem clamp plate in a scissor-like action. Further closure of the test gate would have risked damage to the rig. Further closure of a field gate with the seal bulb pinched in this manner would result in the seal being pulled off the gate. Thus, this test, at only 40-foot head, demonstrated how the bottom seals have been pulled from gates in the field. At 55-foot head, the seal bulb became pinched on the vertical steel surface before the seal contacted the seat bevel (Figure 12B). With the penstock entrance transition section removed, the upper edge of the seat bevel provided a sharp corner which is present on many field installations (Figure 3). This corner catches the seal bulb, aiding in the start of a bulb pinch as the gate is lowered. Water forces alone collapsed the bulb at higher heads (Figure 13A) and bulb pinching was very severe when it contacted the upper corner of the seat bevel (Figure 13B). The seal operation was similar with 1/4-inch seal-to-seat gap. If, for any reason, the gate is opened with unbalanced pressure across the top of the gate, the top seal is probably subjected to a similar action as on the bottom seal. The construction of the hollow bulb music-note seal, with or without brass shielding on the bulb, is too flimsy to withstand the water forces at 40-foot reservoir head, much less at over 100-foot head. A much more rugged seal is required.

Solid Bulb Music-note Seal, Without A Brass Shield

This seal was tested at the same conditions as the hollow music-note seal. The penstock entrance transition section (Figure 10) was omitted, and all the 1/4-inch pipe holes were plugged in the lower leg of the angle iron, which was 2-5/8 inches wide. The seal-to-seat gap was set to zero inches and the reservoir head to 60 feet. The seal bulb did not flatten sufficiently to become a control and the bulb remained retracted. The control point was the angle iron downstream edge. The five center 1/4-inch pipe holes (27/64-inch diameter) were unplugged which allowed reservoir pressure to freely enter the cavity behind the seal bulb. The bulb then remained extended during all test gate operation. As the gate was closed at 60-foot head, the bulb became pinched so severely between the seal stem clamp plate and the seal seat that the test gate could not be closed without risking damage to the rig. The seal gap was increased from zero to 1/8 inch, and at 60-foot head the bulb slid down the seal seat without severe bulb pinching. However, when the head was increased to 195 feet, even with a very wide seal-to-seat gap, 5/16 inch, the seal bulb was pinched (Figure 14). Thus, the solid music-note seal without a brass shield is also unsatisfactory.

Solid Bulb Music-note Seal with a 90° Brass Shield

A section drawing of this seal is shown in Figure 2B. The water jet, striking the underside of the bulb, forces the bulb against the underside of the seal stem clamp plate, tending to flatten the bulb around the clamp plate's lower end. The 90° brass shield keeps the seal bulb round and prevents the bulb from deforming around the end of the stem clamp plate. The seal gap was set at zero inches and the lower angle iron leg length was set to the same length, 2-5/8 inches, as in the previous test. The five 1/4-inch pipe holes were open in the angle iron to give continuous extension of the bulb. The seal was tested at 60-, 80-, and 95-foot head. At these heads, the gate was closed with no pinching of the seal bulb, but the lower edge of the brass shield scrapped hard on the seat bevel, and the shield may be torn loose in field operation, particularly if the lower edge of the shield gets caught on the upper corner of the seat bevel (Figure 15A). Because of this, this seal operation is marginal, and emphasizes the need of all smooth surfaces for the seal bulb to slide upon.

Additional testing of this seal is described in subsequent sections of this report, Hollow Music-note Seal Assembly at Grand Coulee Gates 10 to 18, and Automatic Retraction and Extension of the Music-note Seal on the Bottom Side of a Gate.

Solid Bulb Music-note Seal with a Bulb Brass Shield Greater Than 90°

The primary failing of these seals was the poor bond between the brass and the rubber, as may be seen in Figure 16. Further, if the seal bulb was severely pinched, between the stem clamp plate and seat, the bent shield around the bulb does not return to its full round shape. Also, if the shield on the outside of the stem bent appreciably, it did not return to its flat shape. Two seal sections with different shield designs were tested with continuous extension of the seal bulb, by having the five 1/4-inch pipe holes open in the angle iron.

The solid bulb seal with a brass shield all around the bulb and on the outside of the seal stem (Figure 16A) was tested at 1/4-inch seal-to-seat gap at heads of 60, 80, 92, 112, 135, and 150 feet. A large gap was used to see if this relative stiff seal would reach the seat. Even at 150-foot head, the seal bulb did not contact the seat by 1/16 inch. Therefore, this stiff seal was unsatisfactory. Tests were also run at 1/8-inch seal-to-seat gap and at heads of 60, 92, and 150 feet. At this seal gap and head range, satisfactory sealing was obtained. At the completion of these tests the brass shield on the seal stem was bent and the bond to the rubber was broken over about 80 percent of the stem area.

A solid bulb seal with a brass shield on the outside of the stem and continuing around to the bulb center line is shown in Figure 16B. However, the shield slipped past the bulb center line during the curing operation on the section tested. With the only change in the test gate assembly of zero seal-to-seat gap, the behavior of this seal was observed for gate openings and closures at 60-, 92-, and 150-foot head. At the 150-foot head, gate closure was impossible because the seal bulb caught on the seal seat at the upper corner of the bevel (Figure 15B). This very clearly shows that a brass shield is required on the upper quarter of the bulb surface adjacent to the stem to prevent the bulb from "wrapping" itself around the lower end of the clamp plate as shown. Nearly 100 percent of the bond area was broken between the rubber and brass shielding on the stem.

Hollow Music-note Seal Assembly at Grand Coulee Gates 10 to 18

A hollow music-note seal that represented the Grand Coulee assembly (Figure 17) was installed on the test gate. The field installation included an actuating valve and piping for retraction and extension of the bulb. The seal test section did not include the 90° brass shield because a section with the shield was not available. The seal included a 3/8-inch hole every 2 feet of seal length that permitted water pressure inside the seal bulb. A spring flap contacted the lower surface of the seal bulb. This flap was intended to serve as a seal during retraction and extension of the bulb. The behavior of the seal was observed at 1/16-inch seal-to-seat gap and at heads of 60, 90, 155, and 195 feet. The spring flap gave no seal at all with the seal bulb because the hollow music-note seal was too easily deformed by the water forces (Figure 18A). Further, the seal bulb was pinched on the upper edge of the seal seat at 95-foot head or more in the same manner as the earlier tests on the hollow bulb seal. The seal operation was completely unsatisfactory.

Replacing the hollow music-note seal with the solid bulb seal with the 90° brass shield gave better seal operation (Figure 18B). The seal-to-seat gap was 5/32 inch, which was the resulting gap with no change in the seat shims. With the seal in the retracted position and 195 feet of reservoir head, the minimum pressure obtained on drain side of the seal bulb was 150 feet of water, which is too high for dependable retraction.

Behavior of the Music-note Top Seal

The solid bulb music-note seal with a 90° brass shield was assembled in the rig with the seat beveled to represent the top seat (Figure 19). The seal-to-seat gap was varied from zero to 1/4-inch and the reservoir head was varied from 35 to 195 feet. The seal operated satisfactorily as was expected since the bulb is pulled instead of being pushed over the seat bevel as is the case of the bottom seal. The seal bulb was continuously extended during gate closure. The bulb vibrated somewhat during gate closure, particularly at 90-foot head. The bulb vibration started at a point 1 inch below the bevel and ended midway across the bevel. The seal bulb did not reach the seat at 1/4-inch seal-to-seat gap at reservoir heads less than 90 feet. This condition existed even though 1/16-inch clearance was provided between the bulb and stem clamp plate when no water was flowing. If this clearance is increased, the bulb will reach the seat at heads lower than 90 feet. This applies to the top, side and bottom seals.

Automatic Retraction and Extension of the Music-note Bottom Seal

Test results showed that the best music-note seal design is the solid bulb with a 90° brass shield, and this design was used to develop automatic retraction and extension of the music-note seal bulb. In addition, a small amount of testing was done using the nonshielded, solid music-note seal. A description of this method of retraction and extension of the seal bulb has previously been given. The purpose of these tests was to determine the required dimensions of the steel parts adjacent to the seal which affect the timing of the retraction and extension of the bulb. Foremost in importance was the length of the angle-iron lower leg (hydraulic control for bulb retraction, Edge X, Figure 20) and the thickness of the seal stem clamp plate (hydraulic control for bulb extension, Edge Y, Figure 20). The Hungry Horse penstock gates were the particular installation in mind. The required dimensions are shown on Figure 20. The dimensions given are based on approximately 60 assembly combinations of the variables and these dimensions are applicable with the seat bevel in two positions, high and low. For the high seat bevel, the top edge of the bevel was flush with the top of the seat shim plates in the test rig, whereas the low bevel was 1-5/8 inches lower. The lower seal bevel tended to make the water-jet more vertical relative to the jet with the high seat bevel. To prevent possible damage to the test equipment from excessive water hammer at high heads and at the larger seal-to-seat gaps, three 1/4-inch square metal bars were soldered onto the seal seat, which prevented the seal from completely sealing (Figure 21). During retraction the low pressure behind the seal bulb was measured at the beveled corner of the adapter plate (Figure 20). The maximum subatmospheric pressure recorded was 12 inches of mercury. However, this value was not representative of field conditions because this pressure depended upon the leakages past the seal ends, the angle iron ends, etc. The field conditions represented in these tests were those corresponding only to the gate bottom seal.

The following pertinent points are noted:

(a) The seal seating range on the seat at 195-foot head (laboratory maximum head) is shown on Figure 20. This seating range is 3/4-inch above Point L, the lower end of the bevel, to 1-1/2 inches below Point L. The three 1/4-inch square metal bars soldered to the seat advanced the timing of the clamp plate control. Without the bars, the seating range would be shortened and concentrated at the lower end.

(b) Since the bulb seats further down the seat with an increase in head, the seating range applicable to Hungry Horse (265-foot head) was estimated to be 3/8 inch below the 195-foot head range.

(c) Decreasing the clamp-plate thickness resulted in the bulb seating later--further down the seat, other factors remaining the same.

(d) Decreasing the angle iron leg, D, for the bottom seal resulted in the bulb seating earlier--higher up the seat, other factors remaining the same.

(e) The greater the dimension difference of B minus D, the shorter the time interval was between the change-over of control points for retracting and extending the bulb.

(f) Other factors remaining the same, increasing the seal-to-seat gap retarded the time the clamp plate became the control; however, since the seal bulb travels in an arc, the seating position of the bulb on the seat was about the same or slightly higher.

(g) Lowering the seat bevel 1-5/8 inches retarded the time when the seal clamp plate control became effective. This, in part, was attributed to the fact that the jet streamlines were more nearly vertical and the jet was nearer the stem clamp plate than with the higher seat bevel. The lower seat bevel resulted in the bulb seating lower on the seat, about 1/4 inch lower at 195-foot head.

(h) It is important that the seal bulb at no time becomes a control. When the bulb is in the retracted position, it must be 1/16 inch or more behind the line drawn from the angle iron toe to the clamp plate (Dimension J, Figure 20).

(i) The seal bulb must not contact either angle iron leg, especially in the retracted position to insure free circulation of water in back of the bulb. On field gates, the heads of the bolts that attach the angle iron to the gate can be utilized to replace the screw height Dimension E (Figure 20).

(j) The main effect of water leakage between the angle iron ends and the rig windows (not a field condition) and through the angle-iron attaching-screw holes was to slightly retard the time of retraction. The accumulated leakage from all sources in the field gates into this area behind the bulb must be kept below some unknown leakage that would prevent retraction of the bulb. Also, if this leakage is high, it will slightly advance the time when the stem clamp plate control becomes effective. Further, the bulb will not seal (extend) if the leakage from behind the bulb is high, for example, the leakage that may occur past the back side of the seal stem and out the spacer bar parting surfaces. Ordinary sealing precautions in the assembly of the seal and gate parts should eliminate the leakages described. A suitable gasket should be used between the angle iron-to-gate parting surface and on both sides of the spacer bar above the seal stem.

(k) At the start of the test gate closure, the volume behind the bulb is filled with water near atmospheric pressure, whereas the same volume in a field gate will be at a higher head. This difference in pressure was thought to have a negligible effect on the behavior of the seal.

(l) The test gate travel was 0.14 inch per second which is about 4.5 times faster than the field gate travel of 0.131 inch per second during the period the seal passes on to the seat. There is undoubtedly a limit of gate speed (higher than the test gate speed) above which the automatic retraction and extension feature will not work, but since the field gate speed is less than the maximum allowable, this condition was satisfied.

(m) In regard to the two side seals on a field gate, the seal bulb should not be allowed to retract, because once retracted, it is likely not to seal (extend); for extension of the bulb, relative movement must occur between the longitudinal axes of the seal and seat. Retraction can be prevented by decreasing the angle iron leg, D, to 1-3/4 inches and decreasing the gap behind the bulb, H, to zero (Figure 20).

(n) As previously mentioned, nearly all testing was done with the solid bulb music-note seal with the 90° brass shield. Since it was desirable to have a seal without the shield, some testing was done with the solid bulb nonshielded music-note seal.

With a 5/16-inch seal-to-seat gap, this seal was seated with the bulb horizontal center line coincident with Edge L (Figure 20) on the seat for a static extrusion test of the bulb. After two 15-minute period at 195-foot head, the bulb showed no tendency to "blow" through the seal clamp plate-to-seat gap. However, if the bulb seats on any part of the bevel and further gate closure follows, the bulb will not slip on the seat because of the high-friction force, and the bulb becomes pinched in a scissor action between the seat and seal clamp plate (Figure 14). Closure of the seal accompanied by water hammer will multiply this undesirable condition. It was concluded that the 90° brass shield was required because the shield restrains the distortion of the seal bulb, and it does much towards keeping the bulb section round.

Thus, automatic retraction and extension of the solid music-note bottom seal was achieved (Figure 22).

After reviewing all testing on the music-note seal, it was apparent that the position control of the bulb is inadequate which makes this seal marginal as a bottom seal. In order to control the position of the seal bulb, a second stem was added, and this seal has been designated the double-stem type of seal.

DOUBLE-STEM SEAL DESIGNS

The double-stem type of seal is shown in Figure 23. Steel collars (spacers) were used in the screw holes in the seal stems in order to tighten the attaching screws and to minimize water leakage through the screw holes (Figure 25). Using the stem collars resulted in little or no compression on the stems, thus permitting the seal to "float" somewhat.

All Rubber Double-stem Seal

A section drawing of this seal is shown in Figure 24. The test seal had 9/16-inch instead of 1/2-inch nominal thick stems with cemented-on 1/32-inch-thick seal strips on the stem ends in place of the molded seal as shown. The seal bulb was operated by two methods, (a) continuous extension and (b) actuating valve and piping. This seal assembly was tested at zero seal-to-seat gap and at heads of 60, 95, 155, and 195 feet of water. Tests were repeated at these heads for 1/8- and 1/4-inch seal-to-seat gaps. At 1/4-inch seal-to-seat gap, the seal bulb, when extended by the actuating valve and piping method, did not reach the seat at less than 150-foot reservoir head; likewise, at 1/8-inch seal-to-seat gap, 60 feet was required to assure a seal. At zero seal-to-seat gap, the seal bulb, when extended, reached the seat at the lowest reservoir head, 35 feet, used during these tests. This information was obtained by observing the seal behavior with the gate in the closed position. A plot of bulb extension versus reservoir head with the bulb center line coincident with the seat top surface is shown in Figure 25, Curve No. 1. Although the pressure conditions around the bulb for Figure 25 are different than those with the seal further down the seat (gate in the closed position), the curve agrees reasonably well with the observations of the seal in the lower postion (gate closed). The fact that 150 feet of reservoir head is the minimum head required to obtain a seal for 1/4-inch seal-to-seat gap is not desirable. Doubtlessly, a seal can be obtained at the lower heads and higher seal-to-seat gaps by removing metal from both clamp plates adjacent to the seal bulb, thus giving the bulb more space to extend outward when reservoir head is applied to the stem side of the seal. Other than noted above, this seal assembly operated satisfactorily when the actuating valve and piping method for operating the bulb was used. During gate closure with the bulb in the retracted position, the bulb vibrated somewhat at 155-foot reservoir head as the bulb passed by the bevel on the seat. This was probably due to the unstable water-pressure conditions next to the seal bulb, as well as a "loose" seal assembly with the stem collars installed. In opening the gate, the seal bulb retracted well when the reservoir pressure was drained from the cavity behind the seal. At this time, this seal was the best to date, and sufficient seal was ordered for field testing one gate at Grand Coulee Dam. The tests were conducted in October 1950 using an actuating valve and piping to retract and extend the seal bulb. The tests were reported successful, and a copy of the field report is given in the appendix of this report.

This seal assembly will not operate satisfactorily with zero seal-to-seat gap and with the seal bulb continuously extended. At more than 135-foot reservoir head, the bulb became pinched between the seat and upper clamp plate during gate closure. The frictional resistance of the rubber bulb on the steel seat was too great to permit slippage of the bulb on the seat. (Figure 26A.) This bulb pinching is not likely to occur if the penstock entrance is blended smoothly with the seat bevel, which eliminates the upper corner on the seat level. Bulb pinching did not occur at 1/8-inch seal-to-seat gap and 195-foot reservoir head (Figure 26B). The test gate speed was 0.14 inches per second, and the higher the gate speed, the more likely the seal bulb well be pinched.

<u>Shielded Bulb, Reinforced Stem, Double-stem Seal</u>

Several designs were made of this type of seal (Figures 23, 27, and 28). The reinforcing brass plates were molded into the seal stem to further minimize the chance of pulling the seal from the gate should the seal bulb become pinched on the seat. The brass stem reinforcing plate was made two-piece for seal stem flexibility (Figure 27). As shown in Figure 23B, the two-piece reinforcing plate "floated" from its centralized position during the curing. The single-piece reinforcing plate shown in Figure 29 did not float because lugs were punched in the plate that kept the plate centered during curing (Figure 23A).

Figure 28 shows as intergral bulb-lower stem brass shield. It also has 1/16-inch-diameter holes which fill with rubber during curing to improve the brass-to-rubber bond. The 180° brass shield around the bulb on all of these seals was slotted with the intention of obtaining as much of a rubber-to-steel sealing surface as possible. Since the water forces and friction on the seat tend to turn the seal bulb counterclockwise during gate closure (Figure 25), the slots were cut off-center so that when the seal bulb was in the turned position, the rubber surfaces were in contact with the seal seat. Some of the seal test sections did not have these slots in the brass shield completely filled with rubber, which resulted in an inferior sealing surface. This poor molding, however, could undoubtedly be corrected.

All of the brass reinforcing plates in the seal stem made the seal too stiff for satisfactory operation. The bulb reached the seat and sealed at 1/8-inch seal-to-seat gap and 150 feet of reservoir head, but the bulb did not seal by 1/32 - to 1/16-inch at 1/4-inch seal-to-seat gap and 195-foot reservoir head. Further, the brass reinforcing plates became bent during extension of the seal bulb, and the plates tended to stay bent during bulb retractions, thus retarding the bulb movement.

The addition of the 180° brass shield on the bulb did improve the seal operation by preventing the bulb from getting pinched on the seat at zero seal-to-seat gap and 195-foot reservoir head, which occurred on the double-stem seal without a bulb shield. A plot of seal bulb extension versus reservoir head for four double-stem seals is shown in Figure 25.

Reworked Double-stem Seals for Shasta Dam

The penstock gates at Shasta Dam include the music-note seal (Figure 30), and the bottom seal, in particular, has given unsatisfactory service. The gate assembly included an actuating valve and piping for retraction and extension of the seal bulb. The prototype seal assembly included a metal spring flap intended for a seal to separate the reservoir water from the cavity behind the bulb when the bulb is retracted or extended. The double-stem seal cannot be used on the bottom seal on the Shasta gates, because of space limitations. Therefore, the Mechanical Division proposed two seals for replacement of the music-note seal (Figures 31 and 32). Each seal proposal was a rework of the double-stem seal. The seal with the thin-bolted section (Figure 31) was unsatisfactory for the following reasons:

(a) With 1/8-inch seal-to-seat gap, the bulb could not be retracted after it had been extended at reservoir heads of 97 or more feet because of excessive leakage into the cavity behind the seal bulb (Figure 33). The holes in the thin-bolted section for the three 3/8-inch cap screws and the four 7/16-inch-diameter spacers elongated when the bulb was extended. The spacers were required so that the cap screws could be tightened and to prevent the plate below the seal from turning counterclockwise. When an attempt was made to drain the cavity behind the bulb for retraction, the elongated holes continued to leak reservoir head into the cavity; thus, the seal bulb did not retract. If the bulb will not retract, it will become pinched on the upper corner of the seat bevel.

(b) In view of (a), holes are not permissible in the thin-bolted section, and this section would have to be held by an integrally molded circular section at the end of the thin section. This seal would require a new mold applicable for a single project, and thus make the seals for Shasta Dam expensive.

The other seal proposal (Figure 32), which was a double-stem seal with the lower stem cut off near the bulb at an oblique angle, was a satisfactory seal after modifications were made to the seal and the adjacent metal parts. The recommended seal is shown in Figures 34 and 35A. This seal retracted and extended satisfactorily at 195-foot head over a zero to 1/4-inch seal-to-seat gap range and with the cut-off stem end of the seal compressed from 3/32 to 7/32 inch, a 1/8-inch range (Figure 36). The following tests were also made to determine the minimum head at which the sealing could be accomplished:

(a) Zero seal-to-seat gap, 7/32-inch compression on cut-off end of seal requires 70-foot head for a seal.

(b) Zero seal-to-seat gap, 3/32-inch compression on cut-off end of seal requires 45-foot head for a seal.

(c) 1/4-inch seal-to-seat gap, 7/32-inch compression on cut-off end of seal requires 175-foot head for a seal.

(d) 1/4-inch seal-to-seat gap, 3/32-inch compression on cut-off end of seal requires 110-foot head for a seal.

This seal was subjected to 195-foot reservoir head in the extended position, with the bulb above the seat, and with 3/32-inch compression on the cut-off lower stem (Figure 35B). The cut-off stem did not blow free from the steel member. This was possible due to the restraining effects of the 180° brass shield on the bulb against the upper stem clamp plate, and the steel bar on the lower steel member retaining the cut-off stem.

When the gate was closed with the bulb extended, it caught on the upper edge of the seat bevel, particularly at the smaller seal-to-seat gaps. This condition could be duplicated in the field if drain passage from the cavity behind the bulb became plugged--a condition which is not likely to occur. This emphasizes again that the seal seat on future projects should be constructed without sharp edges, and with the seat bevel blended smoothly into the outlet entrance.

Automatic Retraction and Extension of the Gate Bottom Double-Stem Seal

Test results at this time showed that the best double-stem seal operated with the bulb retracted would be one without a reinforced stem or bulb shield (Figure 24). The brass shield is required when the seal bulb is continuously extended and it is necessary to reduce the frictional resistance on the seat as discussed previously. The operation of the double-stem seal is the same with or without a brass shield on the bulb for automatic retraction and extension of the bulb.

The purpose of these tests was to determine the required dimensions of the steel parts adjacent to the seal which affect the timing of the retraction and extension of the bulb. The test gate assembly included the high seat (Figure 37) and a section of a typical penstock entrance transition which is a curved surface adjacent to the seal seat (Figure 10). This section was included because it was thought that it would affect the jet direction past the upper clamp plate which in turn would slightly affect the timing of retraction and extension of the seal bulb. The seal sections were tested with four 12-inch-long rubber strips, 1/4-inch wide by 1/32-inch thick, two strips cemented on the ends of each seal stem, to prevent water leakage past the stems (Figure 38). These strips can be molded integral with the seal (Figure 24). Steel collars were used in the seal stem holes for the upper and lower clamp-plate attaching screws. These collars permitted the clamp-plate screws to be tightened and minimized water leakage through the screw holes in the clamp plates. The low pressure behind the seal bulb during retraction was measured. The maximum subatmospheric pressure recorded was 21 inches of mercury; however, this figure is not representative of field conditions because this pressure depended upon the water leakage past the seal ends, the clamp plates, etc. In a field installation, this subatmospheric pressure may be greater, which should not appreciably affect the results below. The required dimensions for the steel parts are shown in Figure 38. The Hungry Horse Project was the particular application in mind at the time of these tests.

The following pertinent points are noted:

(a) The seal seating range on the seat at 195-foot head (laboratory maximum head) was 1/4 to 1 inch above Point L, the lower edge of the seat bevel.

(b) Since the bulb seats lower down the seat with an increase in head, the seating range applicable to Hungry Horse (265-foot head) was estimated to be 1/4 inch lower than the 195-foot-head range.

(c) Decreasing the upper clamp-plate thickness resulted in the bulb seating later--further down the seat, other factors remaining the same.

(d) Decreasing the lower clamp plate thickness, D, resulted in the bulb seating earlier--higher up the seat, other factors remaining the same.

(e) The greater the dimension difference of B minus D, the shorter the time interval was between the change-over of control points.

(f) Other factors remaining the same, increasing the seal-to-seat gap retarded the time the upper clamp plate became the control.

(g) The seal bulb downstream surface may be used as the control for extending the bulb, or the seal bulb and the upper clamp plate may be used together. The latter condition was the case for Figure 38 as the J dimension was nearly zero.

(h) The main effect of water leakage between the ends of the steel parts and the rig windows (not a field condition) and through the stem clamp plate attaching-screw holes was to slightly retard the time of retraction. The accumulated leakage from all sources in the field gates into this area behind the bulb must be kept below some unknown leakage that would prevent retraction of the bulb. Also, if this leakage is high, it will slightly advance the time when the stem clamp plate control becomes effective. Further, the bulb will not seal (extend) if the leakage from behind the bulb is high; for example, the leakage that may occur past the back side of the seal stem and out the spacer bar parting surfaces. Ordinary sealing precautions in the assembly of the seal and gate parts should eliminate the leakages described. It is recommended that a suitable gasket be used on both sides of the spacer bar near each seal stem (Figure 38).

(i) At the start of the test gate closure, the volume behind the bulb is filled with water near atmospheric pressure, whereas the same volume in a field gate will be at reservoir head. This difference in pressure was thought to have a negligible effect on the behavior of the seal.

(j) The space behind the bulb on the top and two side seals of a field gate would be drained by water passing through the passages near the bottom seal. This requires time and this factor can be provided by controlling the gate speed. As the gate closes and the lower clamp is acting as the control, the suction head must act on the lower clamp plate passages sufficiently long to drain all four sides of the gate to retract the entire seal. The maximum speed of the gate to complete retraction of the entire seal can best be obtained by field tests, and the determination of this factor was not attempted in the laboratory.

(k) The double-stem seal without a brass shield did not become pinched on the seat when it was tested at 195-foot head and zero seal-to-seat gap. However, as previously mentioned, when the penstock profile was omitted, automatic retraction was not used and this seal was operated with the bulb continuously extended, the seal bulb became pinched (Figure 26A).

(l) The test gate travel was 0.14 inch per second which is about 4.5 times faster than the field gate travel of 0.031 inch per second during the period the seal passes on to the seat. There is undoubtedly a limit of gate speed (higher than the test gate speed) above which the automatic retraction and extension feature will not work, but since the field gate speed is less than the maximum allowable, this condition was satisfied.

(m) The principal disadvantage of the proposed automatic retraction and extension of the double-stem seal is that the gate must be opened with the seal seated, thus requiring greater hoisting power than if the gate is opened with the seal retracted. This disadvantage is reduced by using a metal shielded bulb to lower the sliding friction, and the fact the gate would be opened with balanced pressures.

Thus, automatic retraction and extension of the double-stem seal was achieved.

Double-stem Seal without Stem-Attaching Screws, Design No. 1

A drawing of this seal assembly is shown in Figure 39. One feature of this design was that the heavy brass piece incorporated into the seal bulb cannot escape from the gate even if the rubber-to-brass bond fails. A rubber-to-metal seal was provided the full length of the seal (Figure 40A). A second important feature of this seal was that there are no stem-attaching screws, thereby simplifying field assembly and eliminating undesirable water leakages. A disadvantage of this seal was its excessive weight, 5.1 pounds per foot, compared to 3.4 pounds per foot of the double-stem seal with a reinforced stem and a brass shield on the bulb (Figure 23B).

This seal was tested using an actuating valve and piping for retraction and extension. The maximum seal-to-seat gap, 3/16 inch, was limited by the brass piece striking the shoulder on the upper and lower clamp plates. This is a disadvantage, for if the gap to be sealed is greater than 3/16 inch, no seal can be obtained. However, the assembly can be reworked to considerably increase the maximum gap that can be sealed. A 1/8-inch seal-to-seat gap was used during testing to assure sealing. At 40 feet of head, and with the seal retracted, the bulb brass piece contacted the upper clamp plate. At 120-foot head the lower stem buckled and turned the bulb section about 15 degrees (Figure 40B). A part of the jet was caught by the under side of the bulb which caused the distortion of the seal. At 195 feet, the distortion was only slightly worse. The seal sealed satisfactorily at all heads; however, the brass piece appeared to rub tightly on the upper clamp plate.

An attempt was made to reduce the seal distortion by soldering two 1/4- by 3/8- by 12-inch metal bars to the adapter plate to restrain the buckling of the seal stems (Figure 41). The clearance of the brass piece between the two clamp plates was reduced by 1/8 inch by soldering a bar at the location shown on the lower clamp plate. These changes were not satisfactory, as the lower stem still buckled and slipped around the bar. These tests demonstrated that if no stem-attaching screws are used, the stems be held in place by some other means. The seal described in the next paragraph incorporated this requirement.

Double-stem Seal Without Stem-attaching Screws, Design No. 2

A preliminary design of this seal assembly is shown in Figure 42. As shown, the seal stem ends include an integral circular-shaped section that fits into a groove in the adjacent steel parts, and thus prevents the seal stem from buckling. The two grooves, one for each circular section, are separated sufficiently to put a small, initial tension stress in the seal stems. The maximum section dimension of this seal is somewhat less than the double-stem seal with stem-attaching screws (Figure 43). The bulb section of this seal is less of a half circle than the bulb section of the seal with stem-attaching screws which reduces the amount the bulb can extend. However, limited bulb extension is generally desired for seals operated with continuous extension of the bulb, because too much bulb extension will permit the bulb to become pinched more easily on the upper corner of the seat bevel.

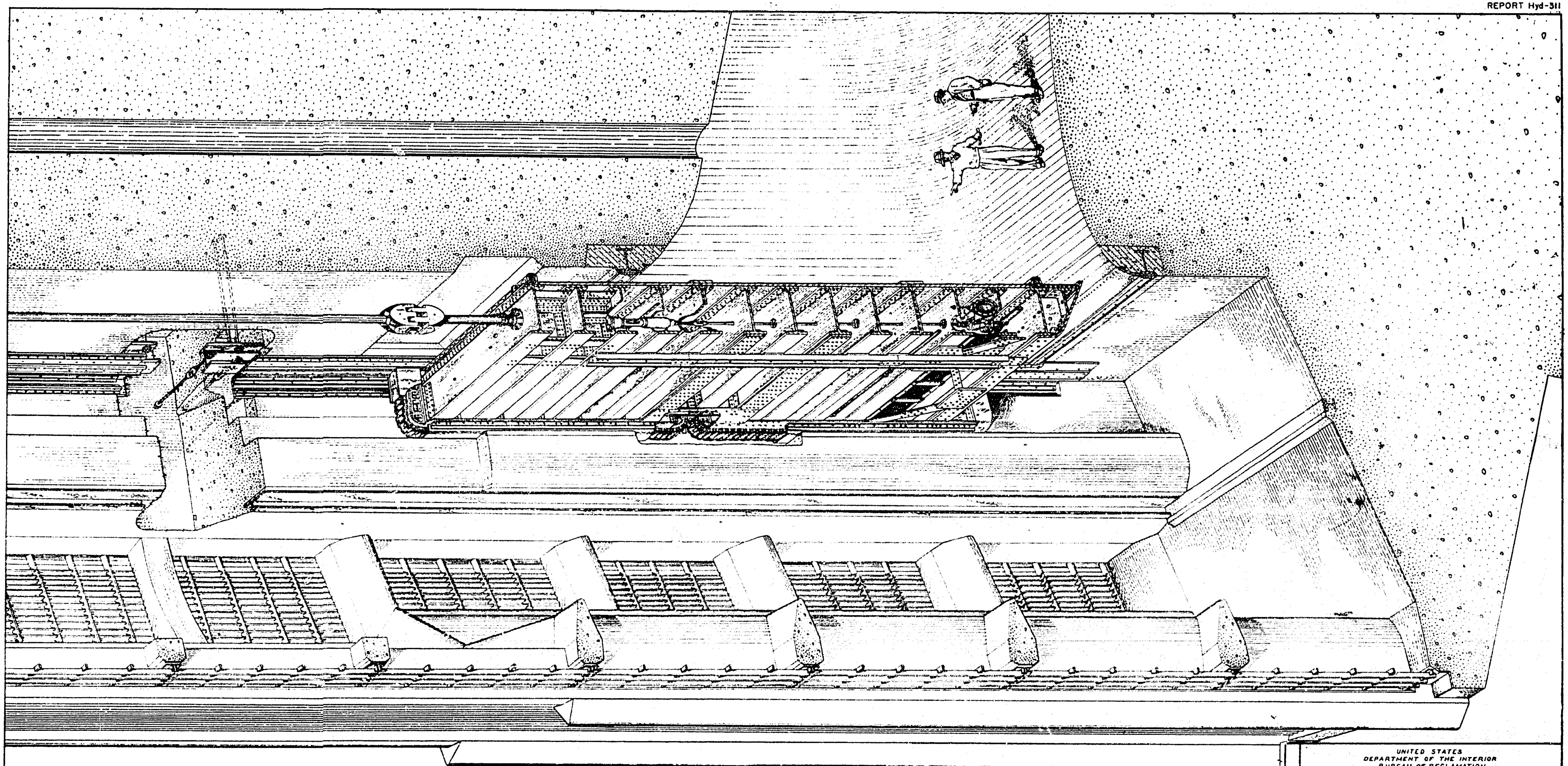
This seal was tested with and without a 180° brass shield vulcanized to the bulb. The seal without the shield was tested first and using the stem clamp plates as shown in the preliminary design. The actuating valve and piping method was used to retract and extend the seal bulb. The bulb retracted satisfactorily at all heads with zero seal-to-seat gap. The seal bulb did not reach the seat, by 1/16 inch, at 1/4-inch seal-to-seat gap and 195-foot head. This appeared to be caused by excessive frictional drag of the upper side of the rubber bulb on the lower face of upper clamp plate. The water jet forced the bulb up and increased the bulb clearance with the top face of the lower clamp plate. Therefore, metal was removed from the upper clamp plate, and metal was added to the lower clamp plate. The recommended assembly is shown in Figure 44 and it is applicable to the bottom, top and side seals of the gate. The bulb reached the seat at 1/4-inch seal-to-seat gap and 195-foot head for a satisfactory seal. Higher heads would result in an even tighter seal. At 3/16-inch seal-to-seat gap, a satisfactory seal was obtained at 100-foot head.

Operation of the seal with the 180° brass shield on the bulb was equally as satisfactory using the recommended seal assembly (Figure 44). A plot of seal-bulb extension versus reservoir head for both seals is shown in Figure 45. The seal bulb with the brass shield extends further at a given head than the seal bulb without the shield. This is because the brass shield reduces the frictional drag of the bulb against the lower face of the upper clamp plate. The brass shield also helps the bulb section maintain its free shape. This is shown in Figure 46, at 160-foot head, the seal bulb with the brass shield became wedged tight between the two clamp plates, thus limiting the bulb extension to slightly over 1/4 inch. With the seal in the position shown in Figure 46A and 3/16-inch seal-to-seat gap, the bulb clearance with the upper clamp plate decreases to zero at 115-foot head. At zero seal-to-seat gap and with the nonshielded seal in the position shown, the seal bulb contacts the upper clamp plate at 105-foot head. The nonshielded seal bulb was flattened sufficiently by the water pressure to provide clearance between the bulb and the lower clamp plate (Figure 46B). The bulb clearance with the lower clamp plate increases from zero at zero head to 1/8 inch at 195-foot head. Figure 45 indicates that the nonshielded bulb will not quite close a 1/4 inch seal-to-seat gap; but when the gate was lowered to the closed-gate position changing the pressure conditions at the seal, a satisfactory seal was obtained.

Both seals were operated at zero seal-to-seat gap and with the bulb extended continuously. The bulb of both seals was not pinched during gate closures at 195-foot head (Figure 46B). This is an advantage over the nonshielded double-stem seal with attaching screws (Figure 24) which was pinched at zero seal-to-seat gap and 195-foot head (Figure 26A).

In reviewing all the seal tests discussed in this report, the double-stem seal assembly of Figure 44 appears most promising, and field tests are recommended.

FIGURE 1
REPORT Hyd-311



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT-WASHINGTON

GRAND COULEE DAM

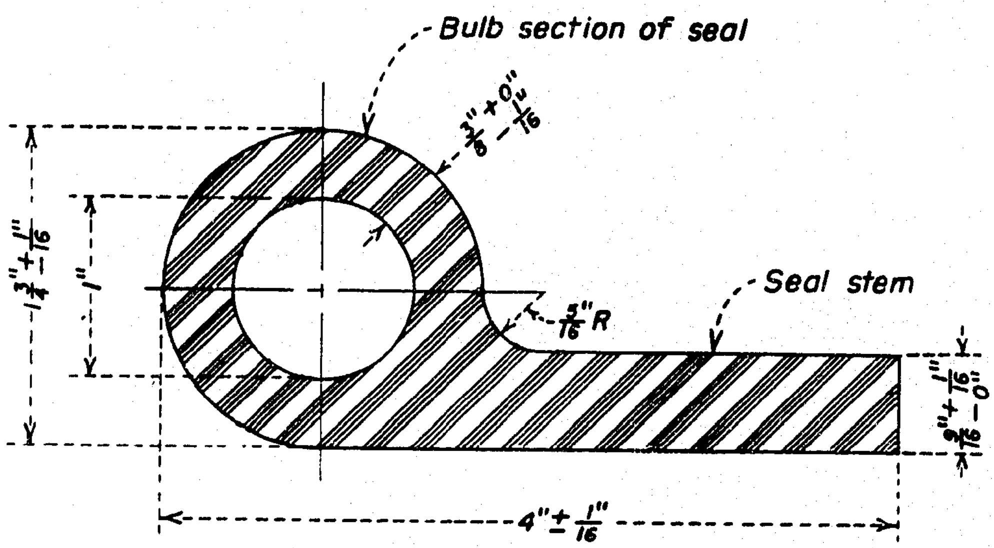
15' x 29.65' PENSTOCK COASTER GATE
GATE INSTALLATION PERSPECTIVE

DRAWN E.A.F. SUBMITTED H Nuzhail
TRACED E.A.F. RECOMMENDED
CHECKED H.E.S. APPROVED

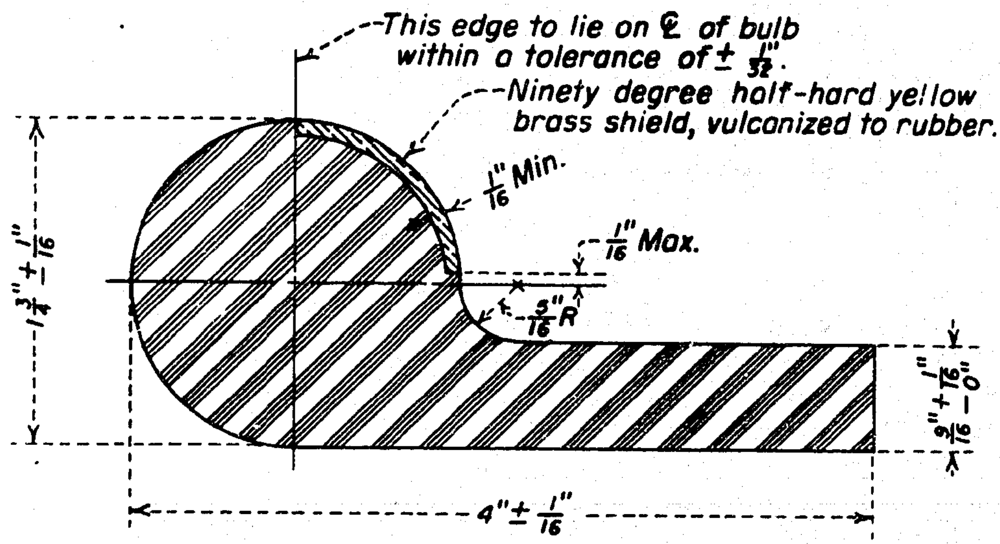
REV 2-10-40 H.E.S.

DENVER, COLORADO, JUNE 15, 1938
SHEET 1 OF 1

222-D-2526



A - HOLLOW BULB SEAL WITHOUT BRASS SHIELD

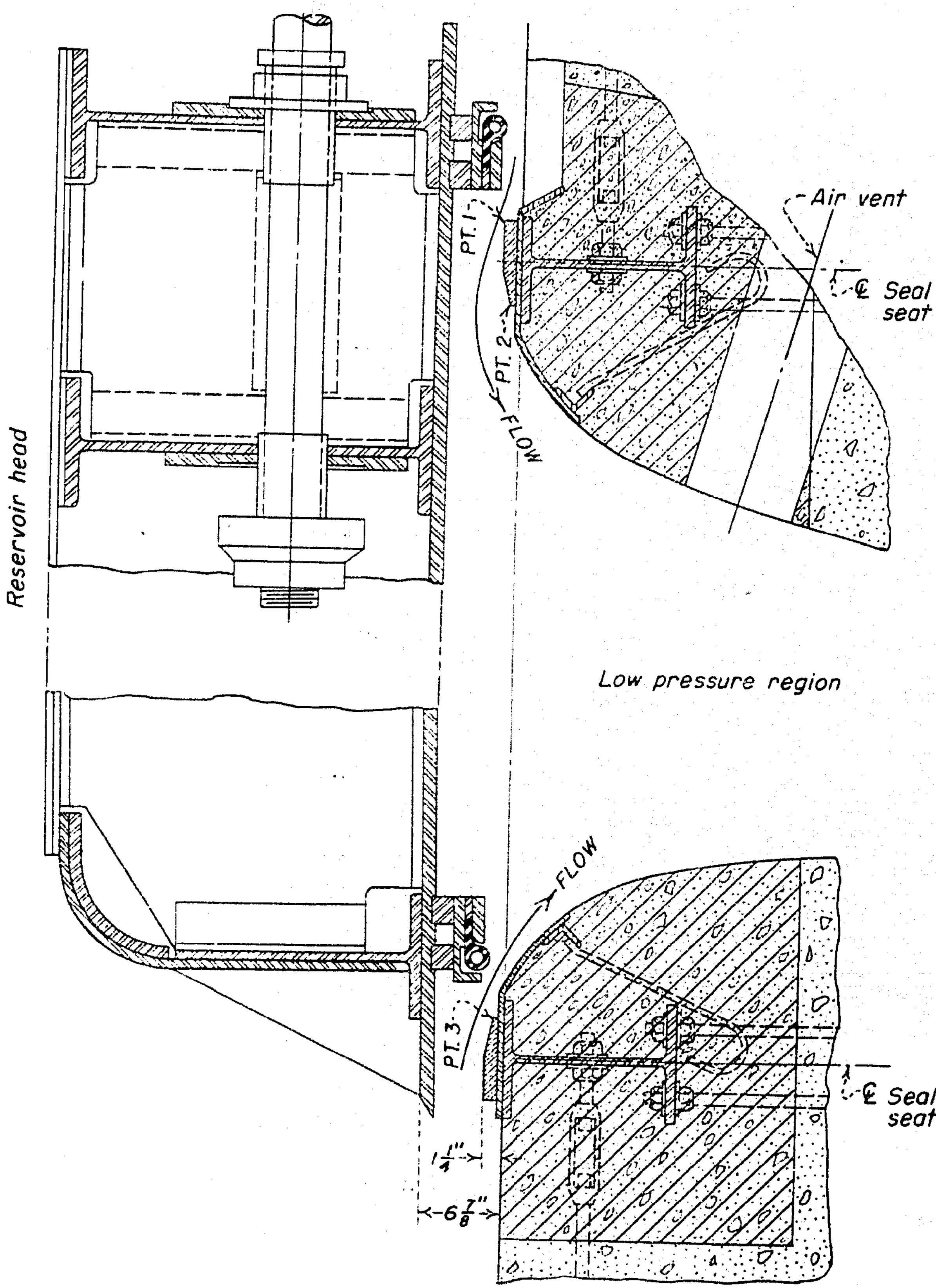


B - SOLID BULB SEAL WITH 90 DEGREE BRASS SHIELD

HIGH HEAD GATE SEAL STUDIES

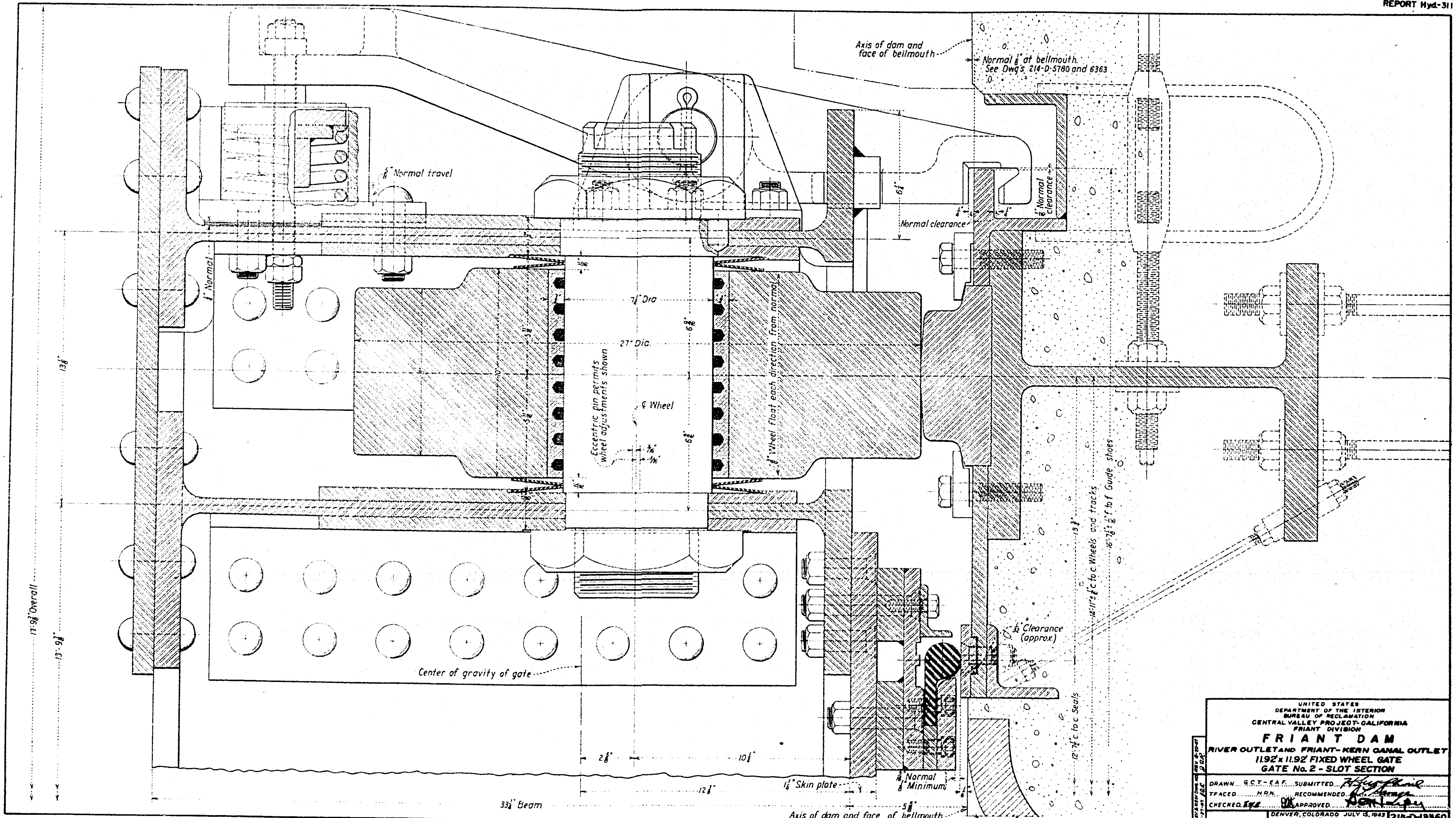
SECTIONS OF MUSIC NOTE TYPE SEALS

320



HIGH HEAD GATE SEAL STUDIES

SEAL SEAT WITH UNDESIRABLE SHARP CORNERS AT POINTS 1, 2 AND 3



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT-CALIFORNIA
FRIANT DIVISION

FRIANT DAM

RIVER OUTLET AND FRIANT-KERN CANAL OUTLET
11.92'x 11.92' FIXED WHEEL GATE
GATE No. 2 - SLOT SECTION

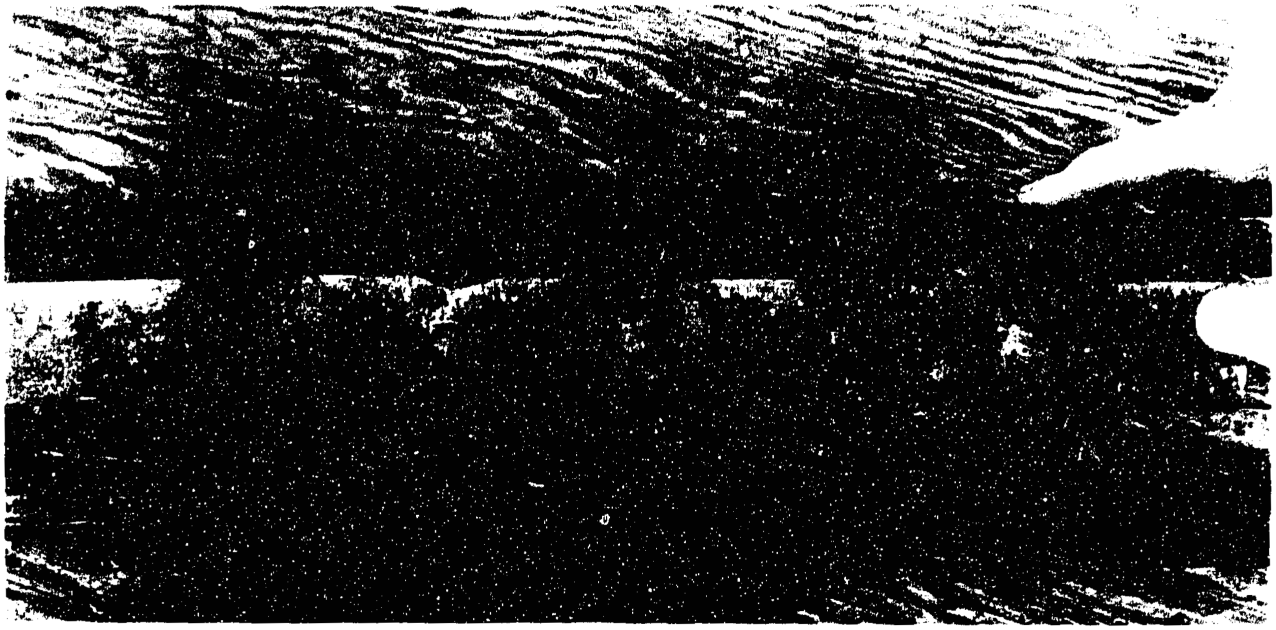
DRAWN G.C.T.-E.A.F. SUBMITTED
TRACED M.R.N. RECOMMENDED
CHECKED E.G.S. APPROVED

DENVER, COLORADO JULY 13, 1943
SHEET 1 OF 1 214-D-13360

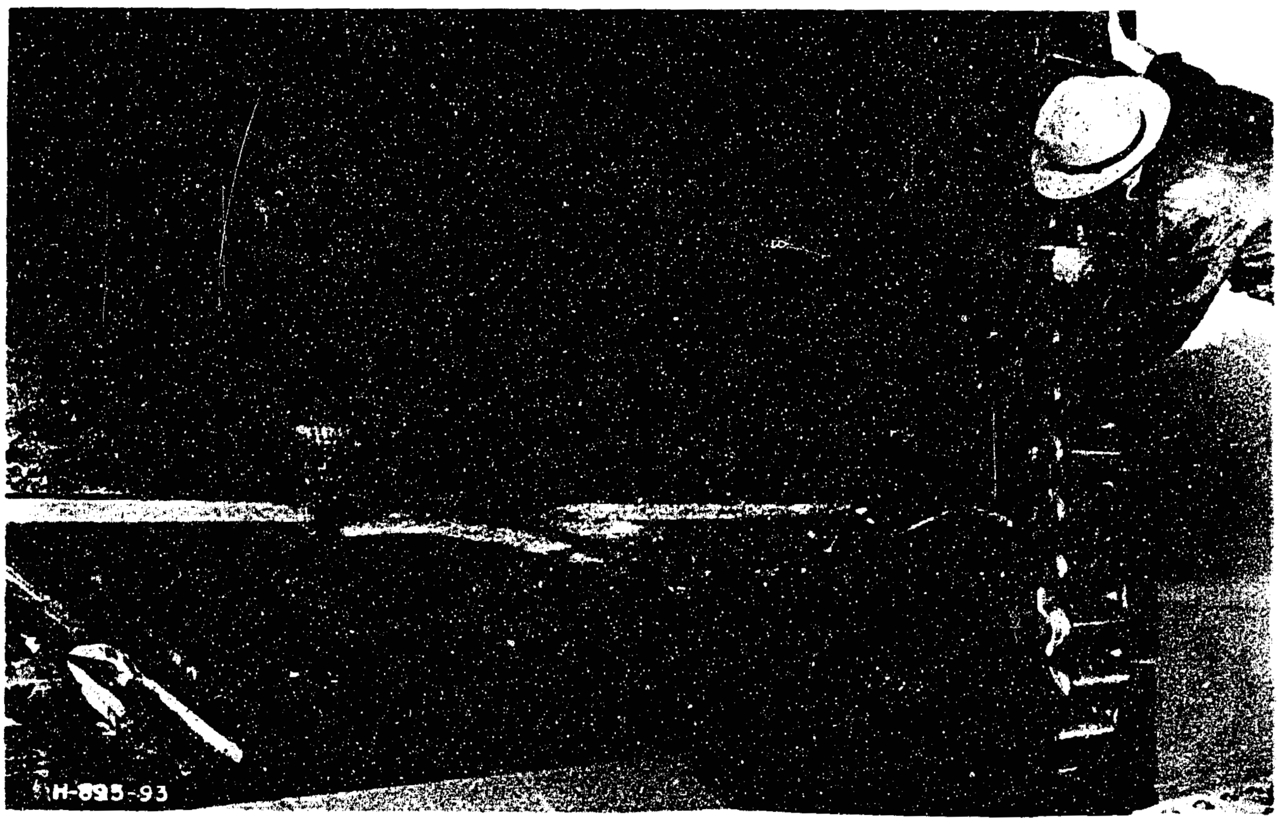
Failure of bottom music note seal with 90 degree brass shield vulcanized to hollow bulb, November 7, 1949.

HIGH HEAD GATE SEAL STUDIES

Music Note Bottom Seal Failure of U-3 Coaster Gate
Shasta Dam, California.



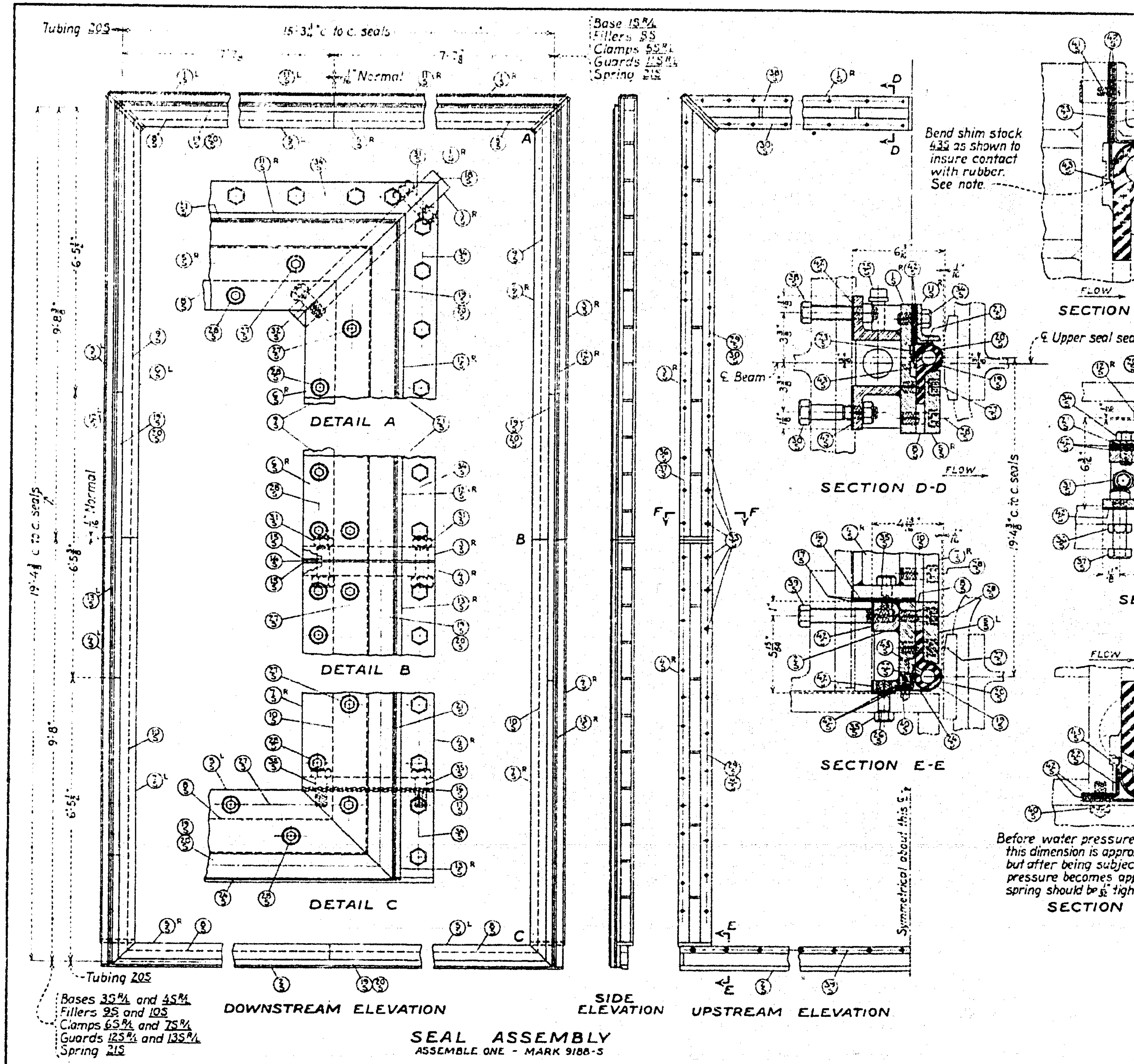
A. Loose 90 degree brass shield showing Allen head clamp plate screw markings, indicating the severe pinching of seal bulb between clamp plate and seat. Same seal as Figure 5.

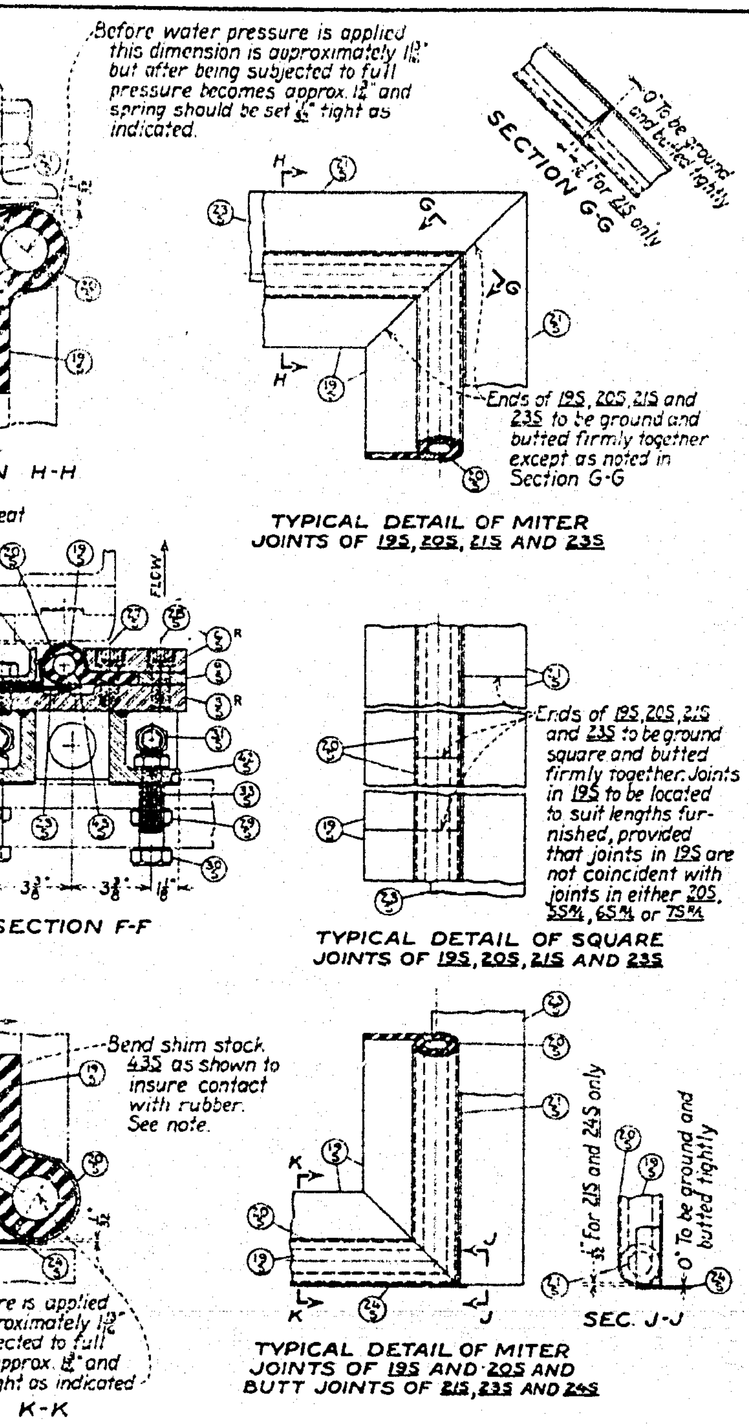


B. East portion of damaged seal shown in Figure 5.

HIGH HEAD GATE SEAL STUDIES

Severe Mutilation of the Bottom Music Note Seal of U-3 Coaster Gate
Shasta Dam, California.





LIST OF PARTS - SEALS FOR ONE GATE

DRAWING NUMBER	PART NO.	NO. REQ'D	DESCRIPTION	MATERIAL † CLASSIFICATION	USED WITH
214-D-9198	1S R	1	Top seal base	Steel	
"	1S L	1	Top seal base	Steel	
214-D-9199	2S	1	Bottom seal base	Steel	
214-D-9200	3S R	1	Vertical seal base	Steel	
"	3S L	1	Vertical seal base	Steel	
"	4S R	1	Vertical seal base	Steel	
"	4S L	1	Vertical seal base	Steel	
214-D-9201	5S R	1	Horizontal clamp	Steel	
"	5S L	1	Horizontal clamp	Steel	
"	6S R	1	Vertical clamp	Steel	
"	6S L	1	Vertical clamp	Steel	
"	7S R	1	Vertical clamp	Steel	
"	7S L	1	Vertical clamp	Steel	
"	8S	4	Horizontal filler	Steel	
"	9S	2	Vertical filler	Steel	
"	10S	2	Vertical filler	Steel	
"	11S R	1	Horizontal guard	Steel	
"	11S L	1	Horizontal guard	Steel	
"	12S R	1	Vertical guard	Steel	
"	12S L	1	Vertical guard	Steel	
"	13S R	1	Vertical guard	Steel	
"	13S L	1	Vertical guard	Steel	
"	14S	3	Shim (laminated)	Steel	
"	15S	6	Gasket	Garlock No. 681 or equivalent	
"	16S	2	Shim (laminated)	Steel	
"	17S	2	Gasket	Garlock No. 681 or equivalent	
"	18S	2	Gasket	Garlock No. 681 or equivalent	
"	19S	△72 L.F.	Rubber seal	Rubber	
"	20S	72 L.F.	Tubing	Steel, brass, stainless steel or CuNi alloy	
"	21S	56 L.F.	Spring	Steel, brass, stainless steel or CuNi alloy	
"	22S	16 L.F.	Spring	Steel	
"	23S	56 L.F.	Spring	Steel	
"	24S	16 L.F.	Spring	Steel, brass, stainless steel or CuNi alloy	
"	25S	2	Air vent	Steel	1S R/L
"	26S	10+2	Dowel	Steel	3, 2S
"	27S	104+10	Socket head cap screw	Steel	[illegible]
"	28S	106+10	Socket head cap screw	Steel	[illegible]
"	29S	12+2	Special bolt with nut	Steel	1, 2, 3, 3S R/L, 4S R/L
"	30S	40+3	Special bolt with nut	Steel	1, 2, 3, 1S R/L, 3S R/L, 4S R/L
"	31S	8+2	Special bolt with nut	Steel	1S R/L, 3S R/L, 4S R/L
"	32S	2+1	Stud with nut	Steel	1S R/L, 3S R/L
"	33S	12+2	Stud with nut	Steel	2, 3S R/L, 4S R/L
No. detail	34S	168+16	3/4" x 1 1/2" Hex head cap screw	Steel	[illegible]
"	35S	26+2	3/4" x 2" Hex head cap screw	Steel	3, 2S, 4S R/L
"	36S	12+2	7/8" x 2 1/4" Hex head cap screw	Steel	1, 2, 3, 3S R/L, 4S R/L
"	37S	34+3	1" x 4 1/4" Hex head cap screw	Steel	1, 2, 3, 3S R/L, 4S R/L
"	38S	22+2	3/4" x 1" Hex hd. bolt with sq nut	Steel	1, 1S
"	39S	22+2	1" x 5 1/4" Hex head cap screw	Steel	3, 2S
"	40S	42+4	3/8" x 3/4" Round head screw	Steel	2S, 22S, 24S
"	41S	12+2	1/4" x 1/2" Round head screw	Steel	[illegible]
"	42S	*	Gasket - 1/16" thick	Garlock No. 681 or equivalent	
"	43S	14 L.F.	2 1/2" x .003" Shim stock	Steel or brass	
214-D-9201	44S	2	Drill for rubber	Steel	19S
X-D-311	45S	2	Drill for rubber	Steel	19S

* Furnish in rolls or sheets in sufficient amount to cover areas under bases 1S R/L, 2S, 3S R/L, 4S R/L, springs 22S, 23S and shim 43S indicated in sections D-D, E-E, F-F, H-H and K-K.

† Where materials are specified on the drawings, but are not further covered by detailed specifications, the contractor shall furnish high class commercial grades of materials that are satisfactory to the contracting officer.

△ Furnished by the government.

NOTES

Parts 22S, 23S and 43S are provided to maintain booster pressure required in removing hemispherical bulkhead in penstock, (see Dwg 214-D-) and are to be removed at earliest opportunity after hemispherical bulkhead is removed.

Part 41S is provided for convenient holding of parts 23S and 43S. Provide holes in 23S for 41S and in 21S to clear heads of 41S.

Contractor shall mark or tag each part with the mark number shown with the corresponding detail, as; 9197-2S

Where a mark number covers more than one shipping length, the contractor shall add suitable subscripts to the mark number to properly identify each length.

Paint threads of 27S and 28S with a non-corrosive thread compound immediately before installation in field.

REFERENCE DRAWINGS

15'x19.05' COASTER GATE LEAF - ASSEMBLY - LIST OF PARTS 214-D-9188
15'x19.05' COASTER GATE FRAME - ASSEMBLY 214-D-2299
15'x19.05' COASTER GATE LEAF - PRESSURE BOOSTING SYSTEM 214-D-
ALLOWANCES AND TOLERANCES FOR METAL FITS X-D-893

GATES 1 AND 2 ONLY

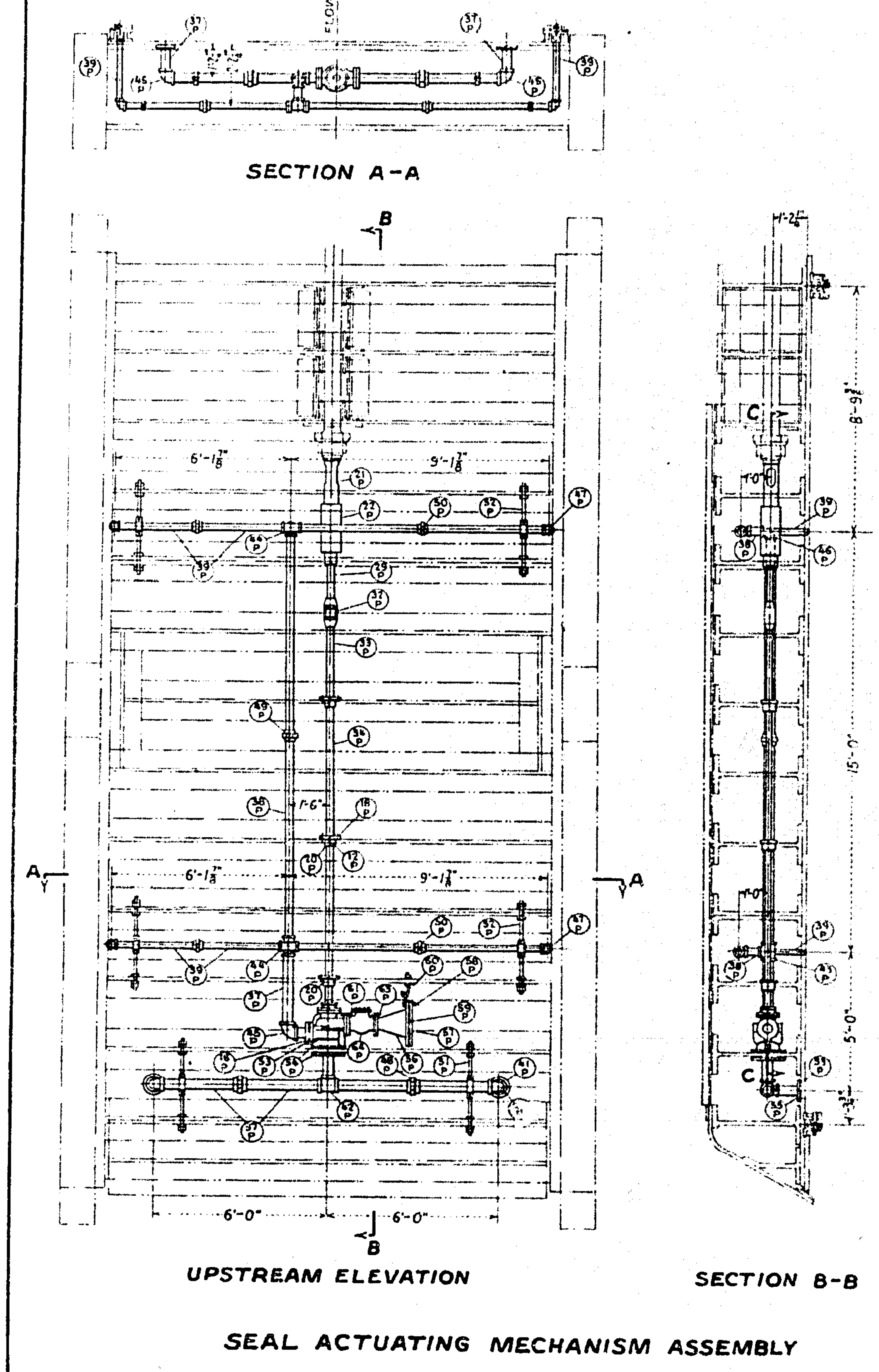
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
KENNETT DIVISION

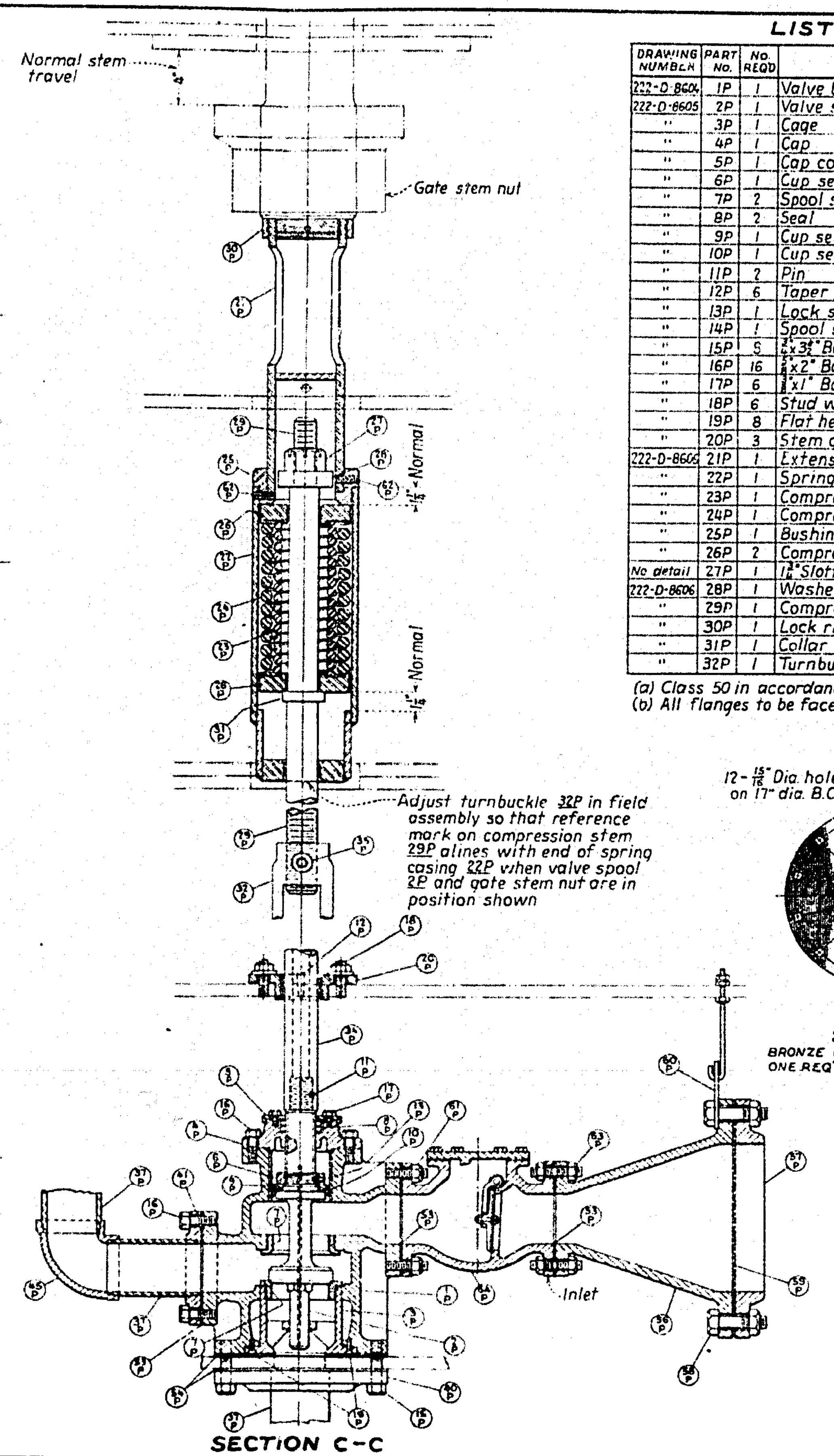
SHASTA DAM
MAIN UNIT PENSTOCKS
15' x 19.05' COASTER GATE LEAF
SEALS
ASSEMBLY - LIST OF PARTS

DRAWN ... D.M.S.	SUBMITTED ... [signature]
TRACED ... H.R.S.	RECOMMENDED ... [signature]
CHECKED ... [initials]	APPROVED ... [signature]
DENVER, COLORADO, NOV. 6, 1942 SHEET 10 OF 20	214-D-9197

REV. 4-23-43 | REV. 1-16-43

FIGURE 8
REPORT Hyd-311





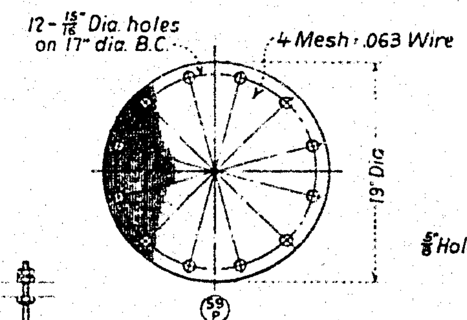
SEAL ACTUATING MECHANISM ASSEMBLY

LIST OF PARTS - SEAL ACTUATING MECHANISM FOR ONE GATE LEAF

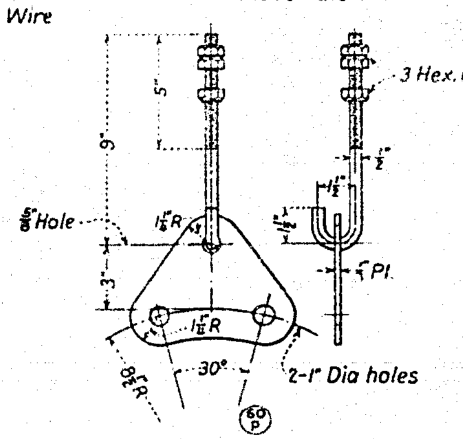
DRAWING NUMBER	PART No.	No. REQ'D	DESCRIPTION	MATERIAL †
222-D-8604	1P	1	Valve body	Gray iron (a) and bronze
222-D-8605	2P	1	Valve spool	Steel and bronze
"	3P	1	Cage	Gray iron
"	4P	1	Cap	Gray iron
"	5P	1	Cap cover	Steel
"	6P	1	Cup seal retainer collar	Steel
"	7P	2	Spool seat	CU. NI. ALLOY OR BRONZE
"	8P	2	Seal	GARLOCK KLOZURE #1497 OR EQUIVALENT
"	9P	1	Cup seal retainer	Steel
"	10P	1	Cup seal	Leather
"	11P	2	Pin	Steel
"	12P	6	Taper pin	Steel
"	13P	1	Lock screw	Steel
"	14P	1	Spool seat wrench	Steel
"	15P	8	¾"x3½" Bolt	Steel
"	16P	16	⅝"x2" Bolt	Steel
"	17P	6	⅜"x1" Bolt	Steel
"	18P	6	Stud with nut and washer	Steel
"	19P	8	Flat head cap screw	Steel
"	20P	3	Stem guide	Steel and bronze
222-D-8606	21P	1	Extension tube	Steel
"	22P	1	Spring casing	Steel and bronze
"	23P	1	Compression spring	Steel
"	24P	1	Compression spring	Steel
"	25P	1	Bushing	Steel
"	26P	2	Compression washer	Steel
No detail	27P	1	1¾" Slotted nut-8 thds per inch	Steel
222-D-8606	28P	1	Washer	Steel
"	29P	1	Compression stem	Steel
"	30P	1	Lock ring	Steel
"	31P	1	Collar	Steel
"	32P	1	Turnbuckle	Steel
222-D-8606	33P	1	Valve stem	Steel
"	34P	1	Valve stem	Steel
No detail	35P	2	½"-13THD x ¾" CUP POINT SET SCREW. PROVIDE WRENCH	Steel
222-D-8606	36P	1	Spanner wrench	Steel
No detail	37P	18 Ft.	4" Standard pipe	Steel
"	38P	16 Ft.	3" Standard pipe	Steel
"	39P	40 Ft.	2" Standard pipe	Steel
"	40P	1	4"x13½"x125# Reducing flange (b)	CAST IRON OR FORGED STEEL
"	41P	3	4"x125# Screwed flange (b)	CAST IRON OR FORGED STEEL
"	42P	1	4"x125# Screwed tee	Cast iron
"	43P	1	4"x3"x3"x125# Screwed tee	Cast iron
"	44P	2	3x2"x2"x125# Screwed tee	Cast iron
"	45P	3	4"x90°x125# Screwed ell	Cast iron
"	46P	1	3"x90°x125# Screwed ell	Cast iron
"	47P	4	2"x90°x125# Screwed ell	Cast iron
"	48P	2	4"x150# Screwed union	Malleable iron
"	49P	1	3"x150# Screwed union	Malleable iron
"	50P	4	2"x150# Screwed union	Malleable iron
222-D-8603	51P	2	Pipe hanger	Steel
"	52P	4	Pipe hanger	Steel
No detail	53P	5	4"x9"x1/16" Gasket	Standard
"	54P	2	4"x13½"x1/16" Gasket	Standard
"	55P	16	⅝"x1½" Cap screw	Steel
"	56P	1	12"x4"x125# FLANGED REDUCER (b) OR EQUIVALENT	Cast iron
"	57P	1	12"x125# Screwed flange (b)	CAST IRON OR FORGED STEEL
"	58P	12	⅞"x4" Bolt with hex. nut	Steel
222-D-8603	59P	1	Screen	Bronze or galv. steel
"	60P	1	Hanger	Steel
No detail	61P	8	⅝"x3" Stud with hex. nut	Steel
"	62P	2	½"x1½" Headless set screw	Steel
"	63P	8	⅝"x3¼" Stud with 2 hex. nuts	Steel
"	64P	1	4" Std. flanged swing check valve (b)	IRON BODY-BRASS TRIMMED
222-D-8606	66P	1	Plug gage	Steel

(a) Class 50 in accordance with Federal specs. QQ-I-652.
(b) All flanges to be faced, and drilled to American Std. 125# templates.

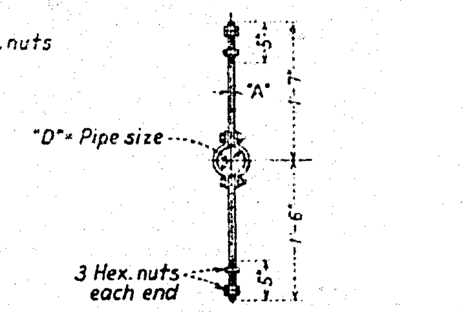
†Miscellaneous materials:- Where materials are specified on the drawings, but are not further covered by detailed specifications, the contractor shall furnish high class commercial grades of materials that are satisfactory to the contracting officer.



SCREEN
BRONZE OR GALVANIZED STEEL
ONE REQ'D. - MARK 8603-59P



HANGER
STEEL
ONE REQ'D. - MARK 8603 - 60P



PIPE HANGER

MARK	NO. REQ'D.	A	D	MATERIAL
8603-51P	2	¾"	4"	Steel
8603-52P	4	½"	2"	Steel

THIS DRAWING IS FOR GATES 4 TO 9 INCLUSIVE SPEC. No. 1010
FOR GATES 1, 2, AND 3 SPEC. No. 905, SEE DWG. 222-D-2541.

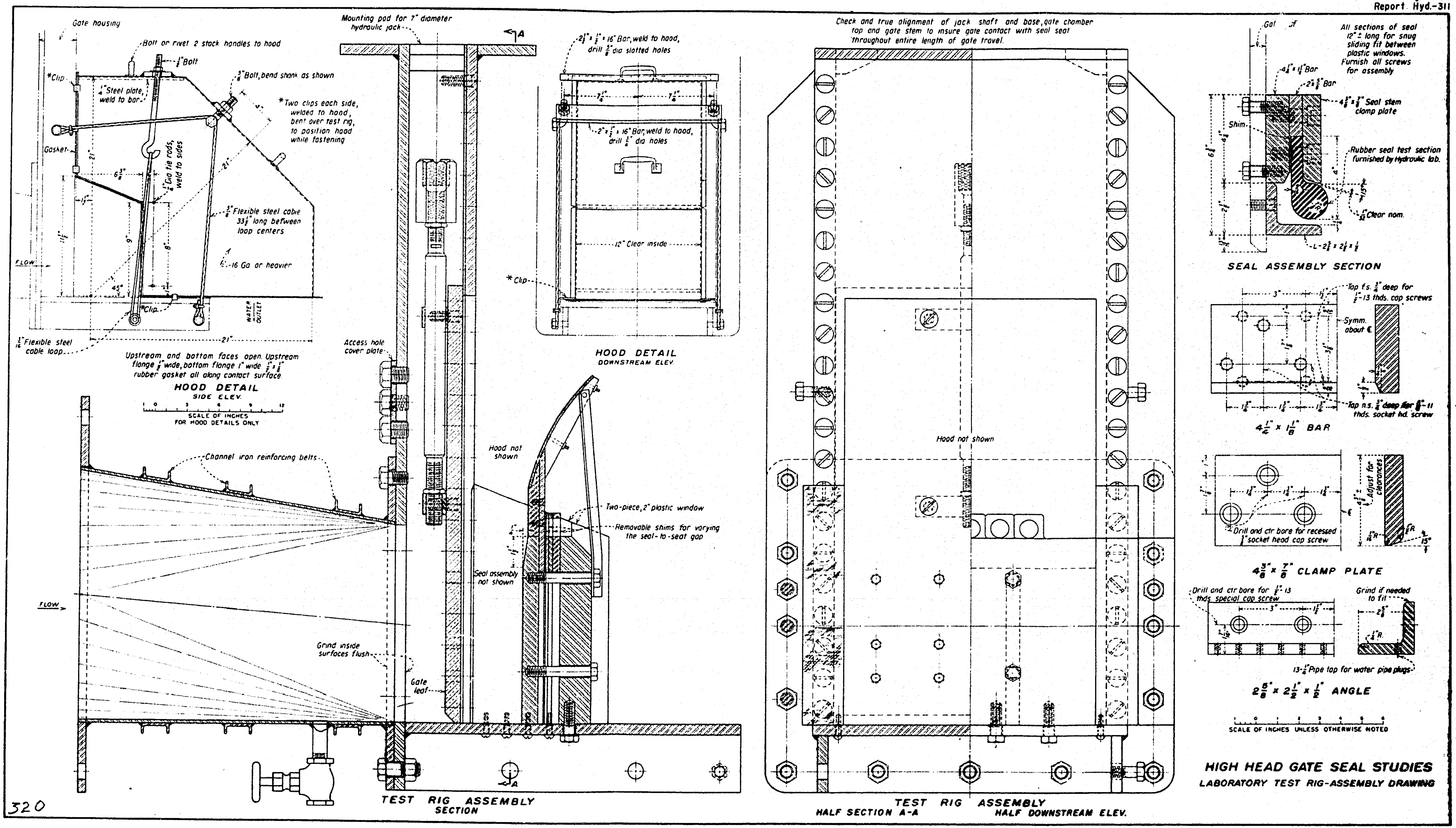
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT-WASHINGTON

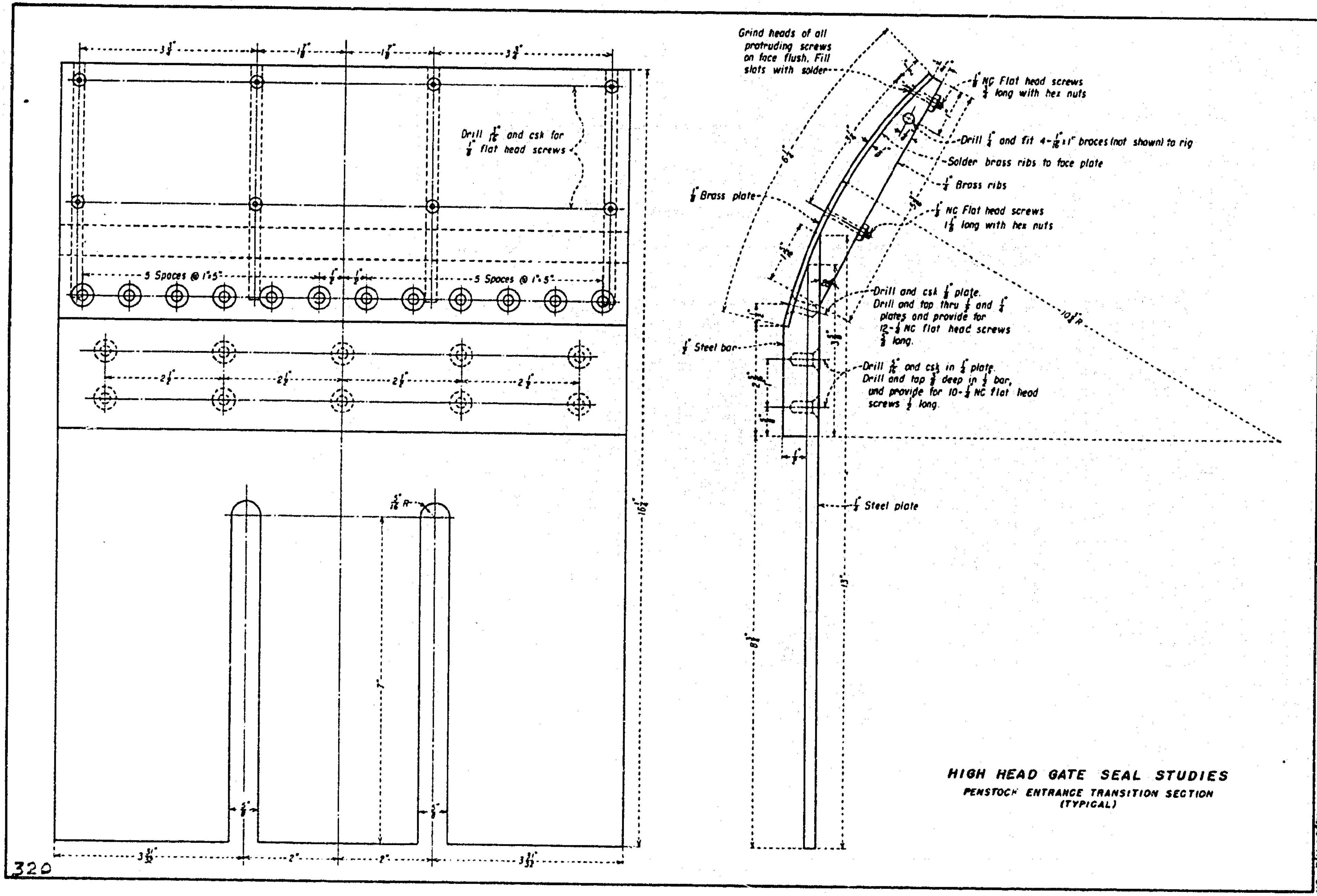
GRAND COULEE DAM

15' x 29.65' PENSTOCK COASTER GATE LEAF
SEAL ACTUATING MECHANISM ASSEMBLY-LIST OF PARTS
GATES 4 TO 9

DRAWN E.C.C. SUBMITTED [illegible]
TRACED E.W.C. RECOMMENDED W. H. Nalder
CHECKED [illegible] APPROVED Walker R. Young

DENVER, COLORADO, JUNE 29, 1942 SHEET 19 OF 25 | 222-D-8603

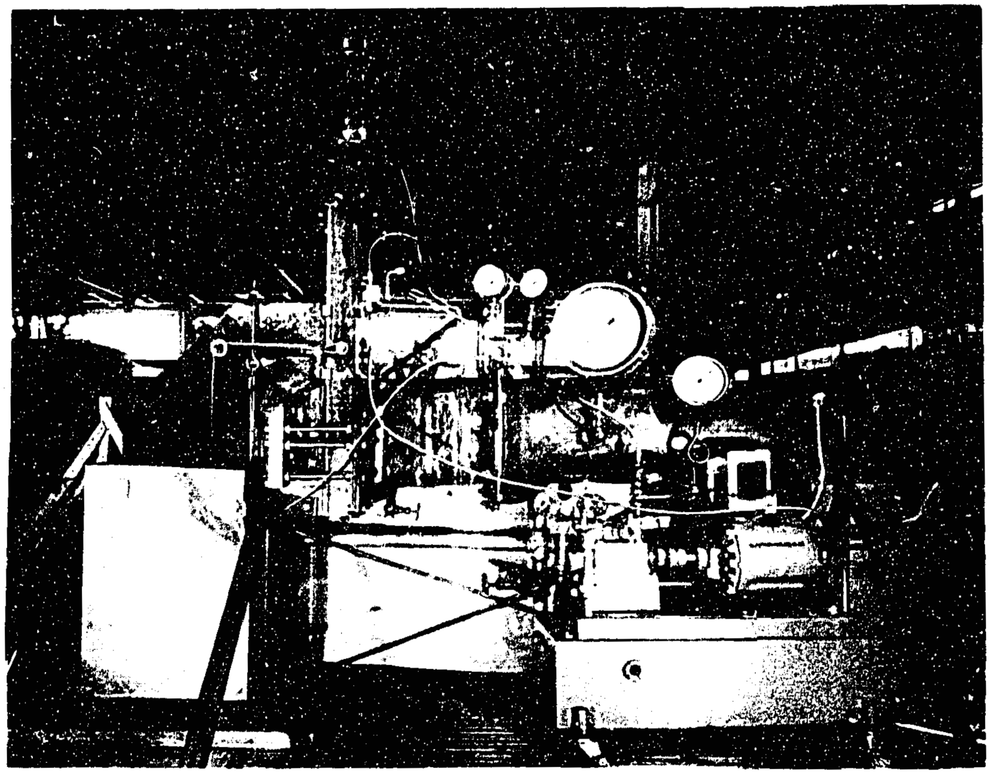

Gate housing
Bolt or rivet 2 stock handles to hood
*Clip
Gasket
FLOW
Two clips each side, welded to hood, bent over test rig, to position hood while fastening
Flexible steel cable loop
-16 Ga or heavier
WATER OUTLET
Upstream and bottom faces open. Upstream flange wide, bottom flange 1" wide rubber gasket all along contact surface.
HOOD DETAIL
SIDE ELEV.
SCALE OF INCHES
FOR HOOD DETAILS ONLY
Mounting pad for 7" diameter hydraulic jack
A
Access hole cover plate
Channel iron reinforcing belts
Grind inside surfaces flush
Gate leaf
Hood not shown
Seal assembly not shown
Two-piece, 2" plastic window
Removable shims for varying the seal-to-seat gap
12" Clear inside
HOOD DETAIL
DOWNSTREAM ELEV.
TEST RIG ASSEMBLY
SECTION
Check and true alignment of jack shaft and base, gate chamber top and gate stem to insure gate contact with seal seat throughout entire length of gate travel.
Hood not shown
TEST RIG ASSEMBLY
HALF SECTION A-A
HALF DOWNSTREAM ELEV.
All sections of seal 12" ± long for snug sliding fit between plastic windows. Furnish all screws for assembly
Shim
Rubber seal test section furnished by Hydraulic lab.
Clear nom.
SEAL ASSEMBLY SECTION
Symm. about ℄
BAR
Adjust for clearances
Drill and ctr bore for recessed socket head cap screw
CLAMP PLATE
Grind if needed to fit
Pipe tap for water pipe plugs
ANGLE
SCALE OF INCHES UNLESS OTHERWISE NOTED
HIGH HEAD GATE SEAL STUDIES
LABORATORY TEST RIG-ASSEMBLY DRAWING
320



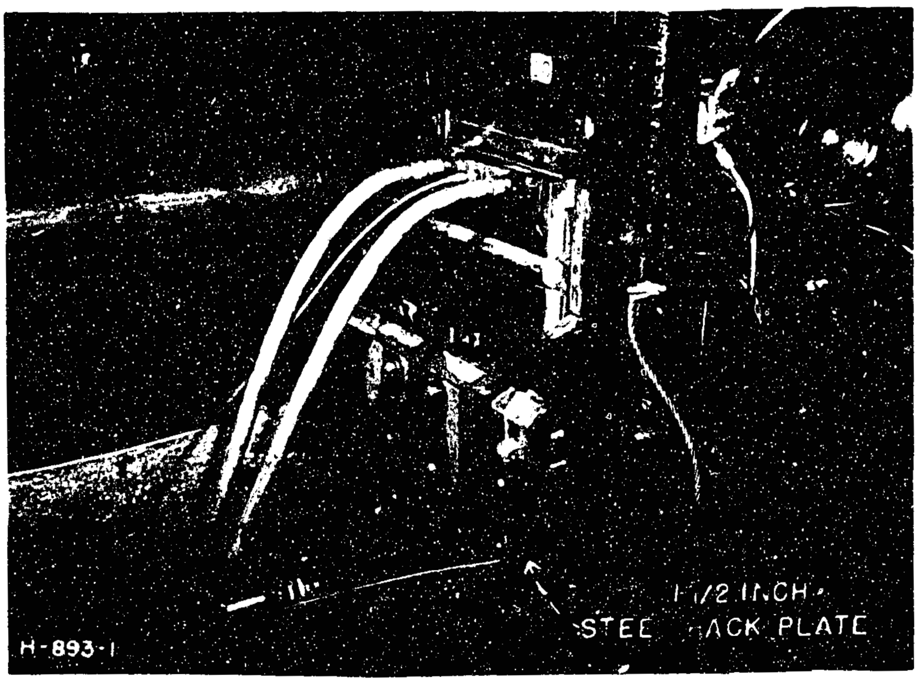
HIGH HEAD GATE SEAL STUDIES

PENSTOCK ENTRANCE TRANSITION SECTION (TYPICAL)

Figure 10
Report Hyd-311



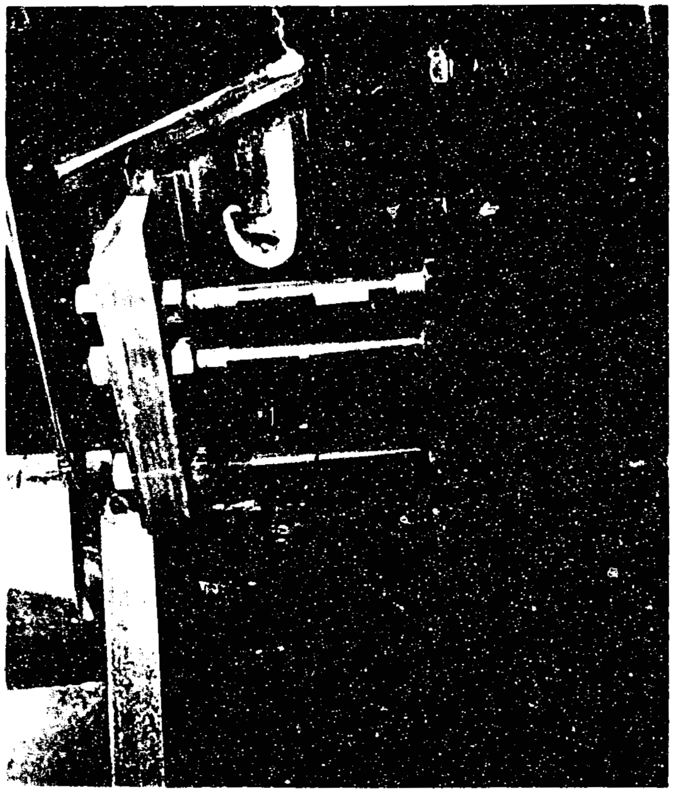
A. Side view showing piping, gages, and general arrangement of equipment.



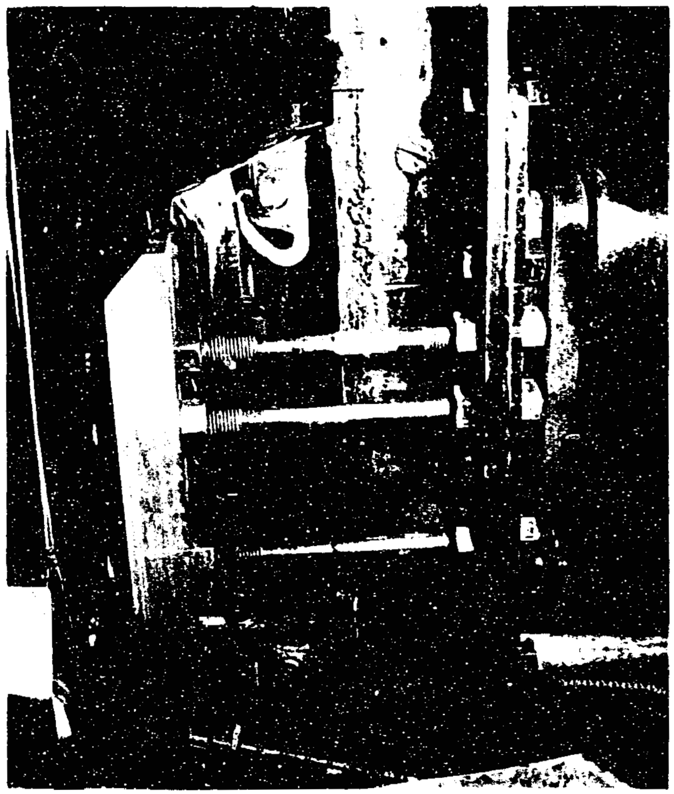
B. View with hood removed showing seal actuating pressure supply hoses, gage line and double stem seal assembly.

HIGH HEAD GATE SEAL STUDIES

Test Rig Photographs



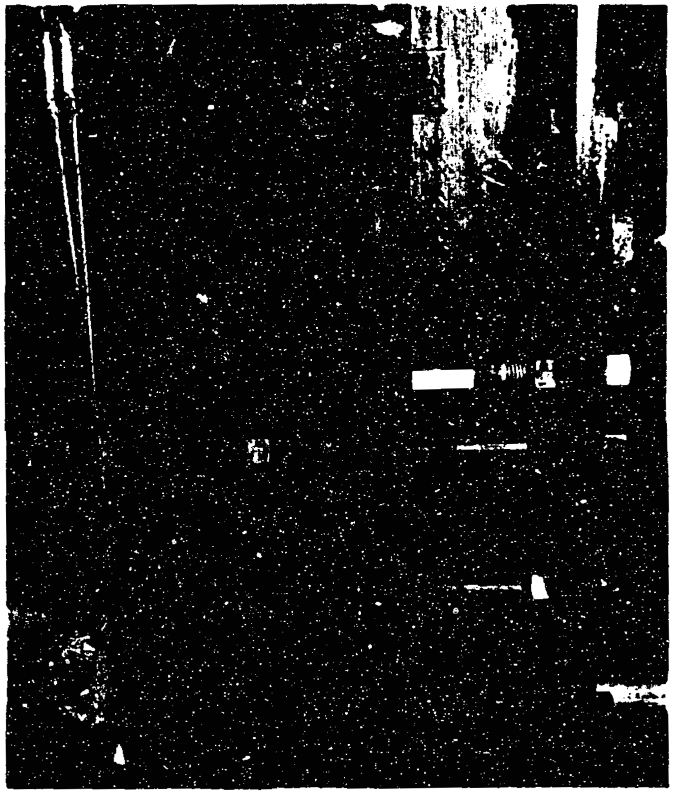
A. End view of seal, assembled with zero seal-to-seat gap, showing the pinched bulb after reaching the seat bevel at 40 feet head. Further closure of gate would pull the seal off the test gate.



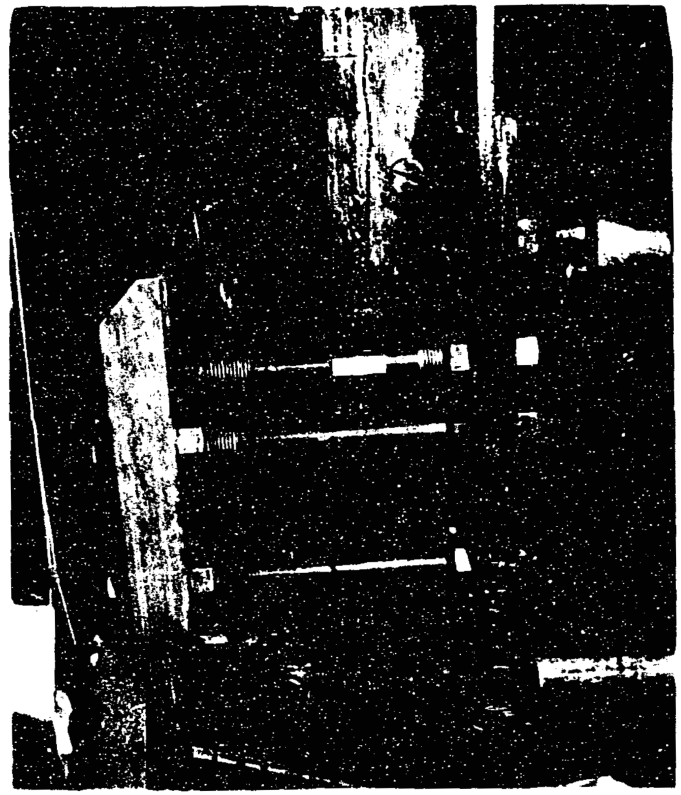
B. At 55 feet head the seal bulb gets pinched on vertical steel surface before the seal bulb reaches the seat bevel, zero seal-to-seat gap.

HIGH HEAD GATE SEAL STUDIES

Manner the Hollow Bulb Music Note Seal Fails at Low Heads without a Sharp Corner at Upper Edge of Seat Bevel.



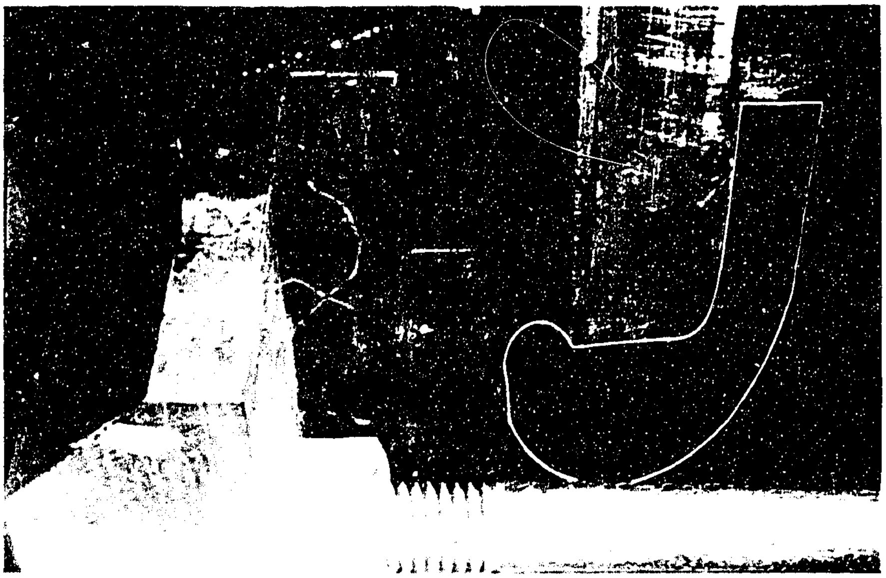
A. End view of seal showing bulb deformation at 195 feet head--no gate movement after applying head. Zero seal-to-seat gap.



B. End view of seal at 160 feet head, zero seal-to-seat gap. Similar bulb pinching occurs at all heads above 40 feet. Further closure of the gate would pull the seal off the test gate.

HIGH HEAD GATE SEAL STUDIES

Manner the Hollow Bulb Music Note Seal Fails at Higher Heads--with a Sharp Corner at Upper Edge of Seat Bevel.



The seal bulb becomes pinched during gate closure at 195 feet head and at a large seal-to-seat gap, 5/16 inch. Without a 90 degree brass shield, seal bulb "wraps" itself around the end of the seal stem clamp plate.

HIGH HEAD GATE SEAL STUDIES

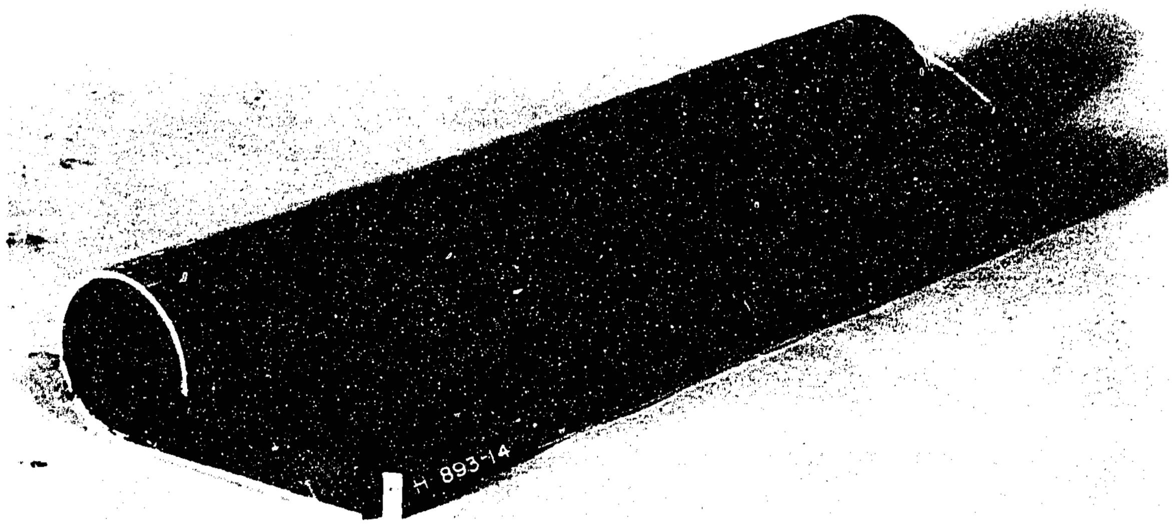
Behavior of the Solid Music Note Seal without a Brass Shield.

A. Seal bulb, with 90 degree shield, sliding down seat bevel at 95 feet head. Lower edge of shield scrapes hard on seat. Ninety degree brass shield prevents bulb from "wrapping" itself around end of seal stem clamp plate, which occurs below.

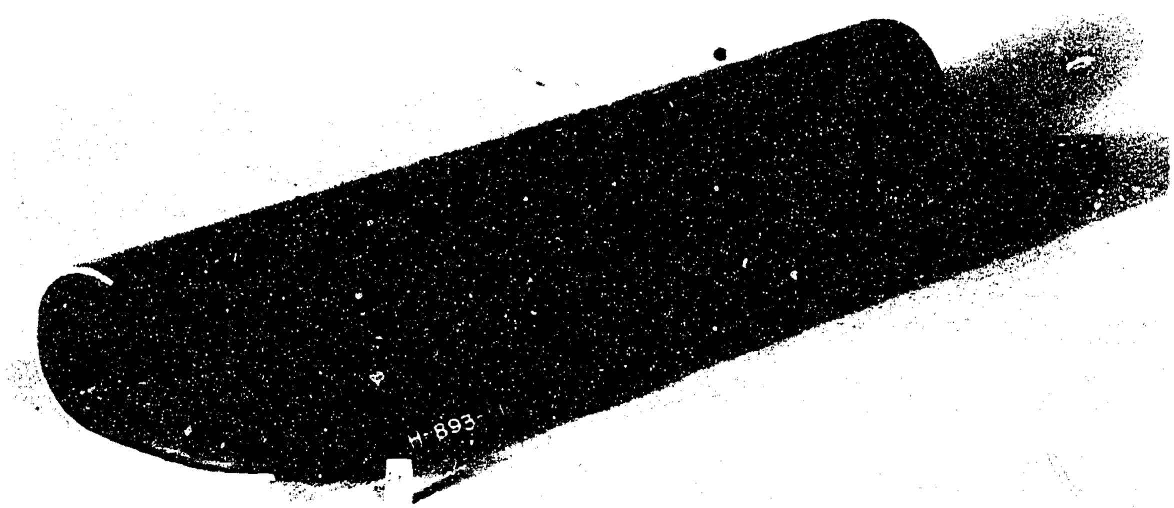
B. Seal with brass shield on lower half of bulb and up right side face of stem. Bulb "wraps" itself around end of stem clamp plate and catches on upper corner of seat bevel during gate closure at 150 feet head.

HIGH HEAD GATE SEAL STUDIES

Behavior of the Solid Music Note Seal with a Brass Shield. Zero Seal-to-Seat Gap--Five 1/4 inch Pipe Holes in Angle Iron.



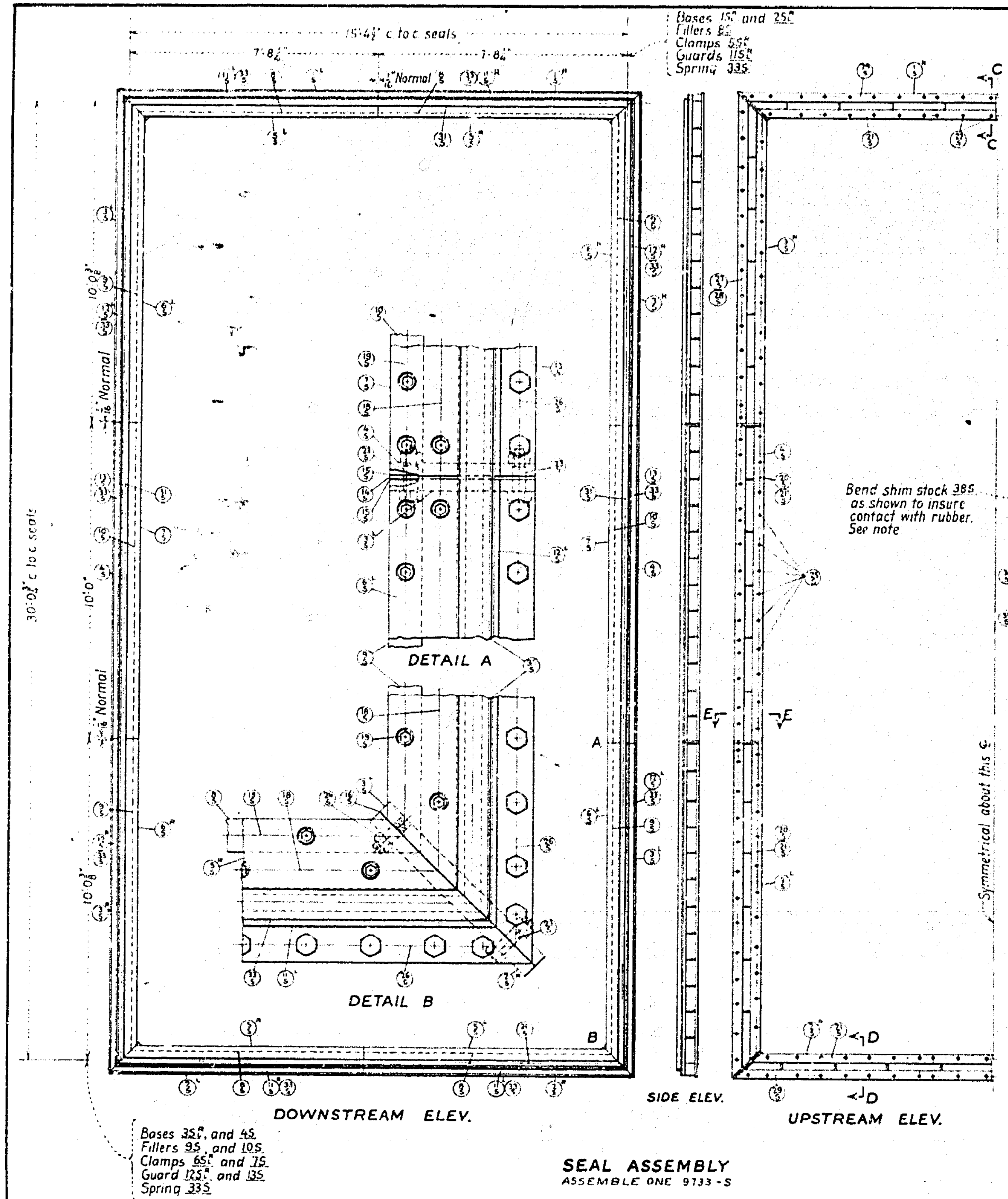
A. Note the poor bond between brass shield and rubber which was typical on seals with large shields.



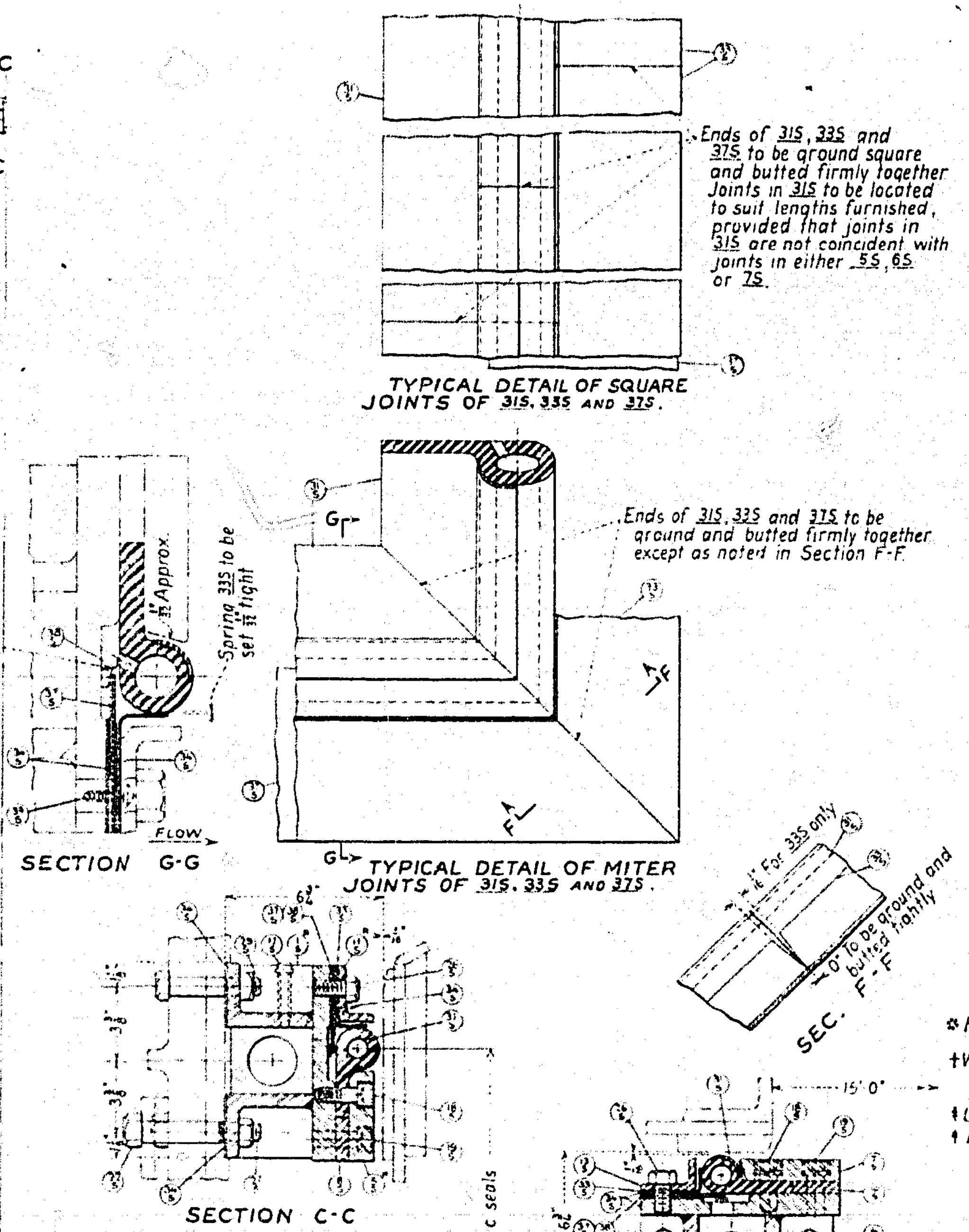
B. Brass shield slipped during molding and shield does not reach to end of stem. The bent shield is the result of laboratory tests.

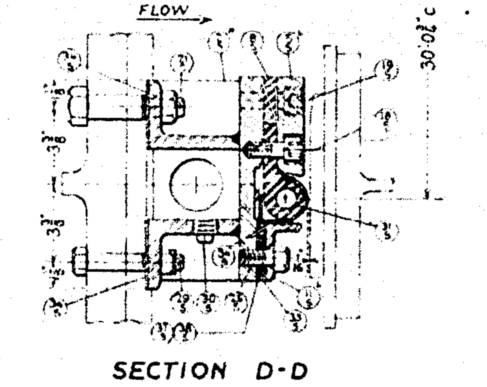
HIGH HEAD GATE SEAL STUDIES

Solid Music Note Seal with brass shields greater than 90 Degrees.



SEAL ASSEMBLY
ASSEMBLE ONE 9133-S





LIST OF PARTS - SEALS FOR ONE GATE

DRAWING NUMBER	PART No.	No REQD	DESCRIPTION	MATERIAL CLASSIFICATION	MAT'L. REF. No.	USED WITH PARTS
222-D-9743	1SR	1	Top seal base	Steel	B55	
"	1SL	1	Top seal base	Steel	B55	
"	2SR	1	Bottom seal base	Steel	B55	
"	2SL	1	Bottom seal base	Steel	B55	
222-D-9744	3SR	2	Vertical seal base	Steel	B55	
"	3SL	2	Vertical seal base	Steel	B55	
"	4S	2	Vertical seal base	Steel	B55	
222-D-9745	5SR	2	Horizontal clamp	Steel	B55	
"	5SL	2	Horizontal clamp	Steel	B55	
"	6SR	2	Vertical clamp	Steel	B55	
"	6SL	2	Vertical clamp	Steel	B55	
"	7S	2	Vertical clamp	Steel	B55	
"	8S	4	Horizontal filler	Steel	B55	
"	9S	4	Vertical filler	Steel	B55	
"	10S	2	Vertical filler	Steel	B55	
"	11SR	2	Horizontal guard	Steel	B55	
"	11SL	2	Horizontal guard	Steel	B55	
"	12SR	2	Vertical guard	Steel	B55	
"	12SL	2	Vertical guard	Steel	B55	
"	13S	2	Vertical guard	Steel	B55	
"	14S	6	Shim	Brass	†	
"	15S	12	Gasket	GARLOCK NO. 681 OR EQUIVALENT		
"	16S	4	Gasket	GARLOCK NO. 681 OR EQUIVALENT		
"	17S	2	Air vent	Brass	†	1S
"	18S	140+8	Socket head cap screw	Steel or Ni.Cu alloy	C75 or F19	[illegible]
"	19S	138+8	Socket head cap screw	Steel or Ni.Cu alloy	C75 or F19	[illegible]
"	20S	20+2	Special bolt with nut	Steel or Ni.Cu alloy	C75 or F19	1,2,3,3S,4S
"	21S	72+6	Special bolt with nut	Steel or Ni.Cu alloy	C75 or F19	1,2,3,1S,2S,3S,4S
"	22S	4+2	Special bolt with nut	Steel or Ni.Cu alloy	C75 or F19	4 and 1S
"	23S	16+2	Special bolt with nut	Steel or Ni.Cu alloy	C75 or F19	1S,2S,3S,4S
"	24S	4+2	Stud with hex nut	Steel or Ni.Cu alloy	C75 or F19	1S,2S,3S
"	25S	12+2	Stud with hex nut	Steel or Ni.Cu alloy	C75 or F19	2 and 4S
No detail	‡26S	280+12	¾" x 1¼" Hex head cap screw	Steel or Ni.Cu alloy	C75 or F19	[illegible]
No detail	‡27S	20+2	⅞" x 2¼" Hex head cap screw	Steel or Ni.Cu alloy	C75 or F19	1,2,3,3S,4S
No detail	‡28S	60+5	⅞" x 4½" Hex head cap screw	Steel or Ni.Cu alloy	C75 or F19	1,2,3,3S,4S
No detail	‡29S	44+4	⅞" x 4½" Hex hd bolt with sq nut	Steel or Ni.Cu alloy	C75 or F19	1,3,1S,2S
No detail	‡30S	2	2" Dia std pipe plug	Steel or Ni.Cu alloy	†	2S
222-D-9745	31S	✱94LF	Rubber seal	Rubber & brass		
222-D-9745	33S	96LF	Spring	BRASS, STAINLESS STEEL OR Ni CU ALLOY		
No detail	‡34S	✱	Gasket - 1/16" thick	GARLOCK NO. 681 OR EQUIVALENT		
X-D-311	35S	2	⅝" Drill for rubber	Steel	†	31S
"	36S	2	⅝" Drill for rubber	Steel	†	31S
222-D-9745	37S	96LF	Spring	Steel	†	
No detail	‡38S	96LF	2½" x .003" Shim stock	Steel or brass	†	
No detail	‡39S	20+2	¼" x ½" Round head screw	Steel	†	[illegible]

✱ Furnish in rolls or sheets in sufficient amount to cover areas under bases 1SR, 2SR, 3SR, 4S, spring 33S and shim 38S indicated in Sections C-C, D-D, E-E, and G-G.
† Where materials are specified on the drawings, but are not further covered by detailed specifications, the contractor shall furnish high class commercial grades of materials that are satisfactory to the contracting officer.
‡ Use 9742 as prefix of the mark number
† Furnished by the Government.

LIST OF DRAWINGS

SEAL ASSEMBLY - LIST OF PARTS 222-D-9742
TOP AND BOTTOM SEAL BASES 222-D-9743
VERTICAL SEAL BASES 222-D-9744
CLAMPS · GUARDS · FILLERS · SHIM · SEAL · BOLTS .. 222-D-9745

REFERENCE DRAWINGS

15' x 29.65' PENSTOCK COASTER GATE LEAF - ASSEMBLY · LIST OF PARTS 222-D-9133
15' x 29.65' PENSTOCK COASTER GATE FRAME 222-D-2162
15' x 29.65' PENSTOCK COASTER GATE LEAF - PRESSURE BOOSTING SYSTEM .. 222-D-6840

NOTES

Parts 37S and 38S are provided to maintain booster pressure required in removing hemispherical bulkhead in penstock. (See Dwg 222-D-6840) and are to be removed at earliest opportunity after hemispherical bulkhead is removed.
Part 39S is provided for convenient holding of parts 37S, and 38S. Provide holes in 33S to clear heads of 39S.
See specifications for marking.

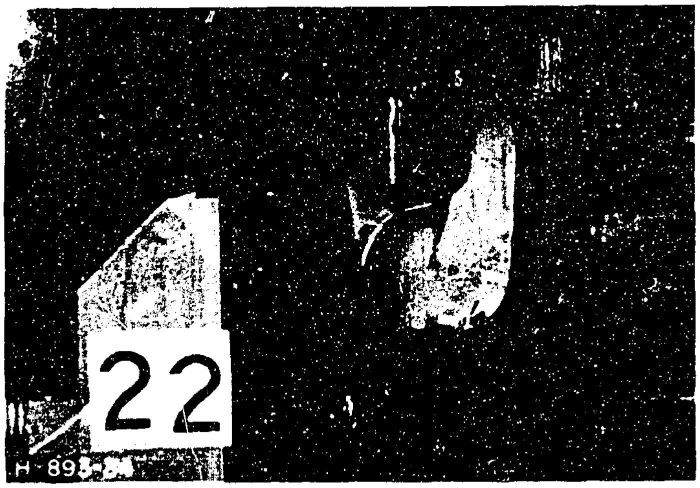
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT-WASHINGTON

GRAND COULEE DAM

15' x 29.65' PENSTOCK COASTER GATE LEAF
SEAL ASSEMBLY - LIST OF PARTS
GATES 10 TO 18

DRAWN E.C.C. ...... SUBMITTED [signature]
TRACED W.M.S. ...... RECOMMENDED [signature]
CHECKED K.G.W. ...... APPROVED [signature]
REV. SHEW DWG. 9-7-45
DENVER, COLORADO JUNE 6, 1942 SHEET 10 OF 20
222-D-9742

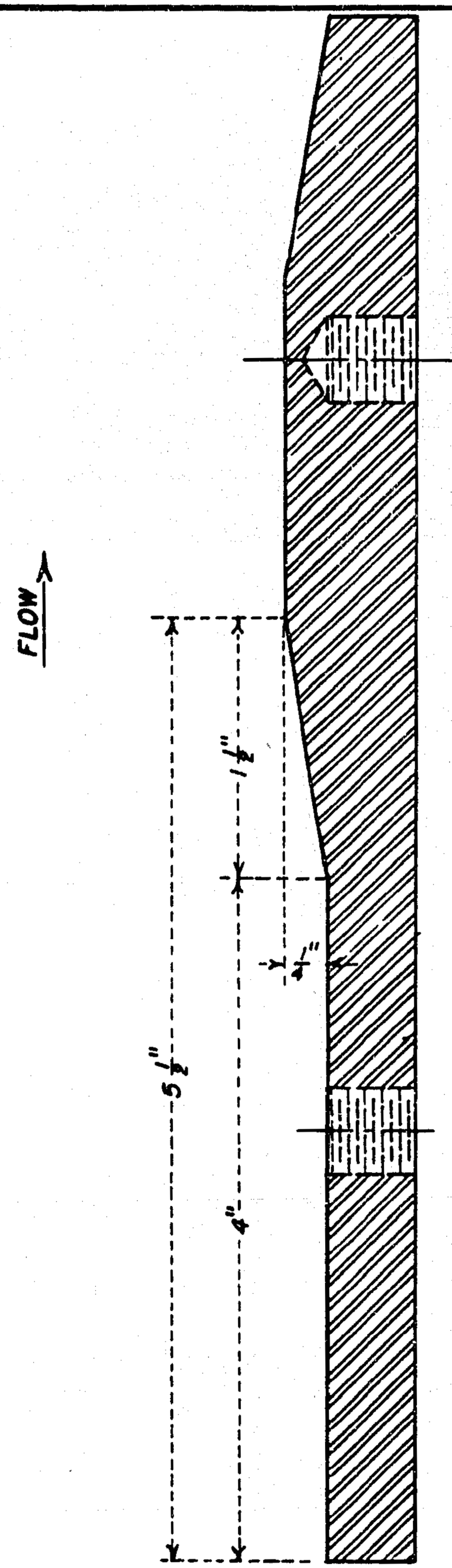
A. Hollow bulb music note seal without a shield, 195 feet head. Note the complete absence of a seal with bulb spring during retraction. 1/16 inch seal-to-seat gap.



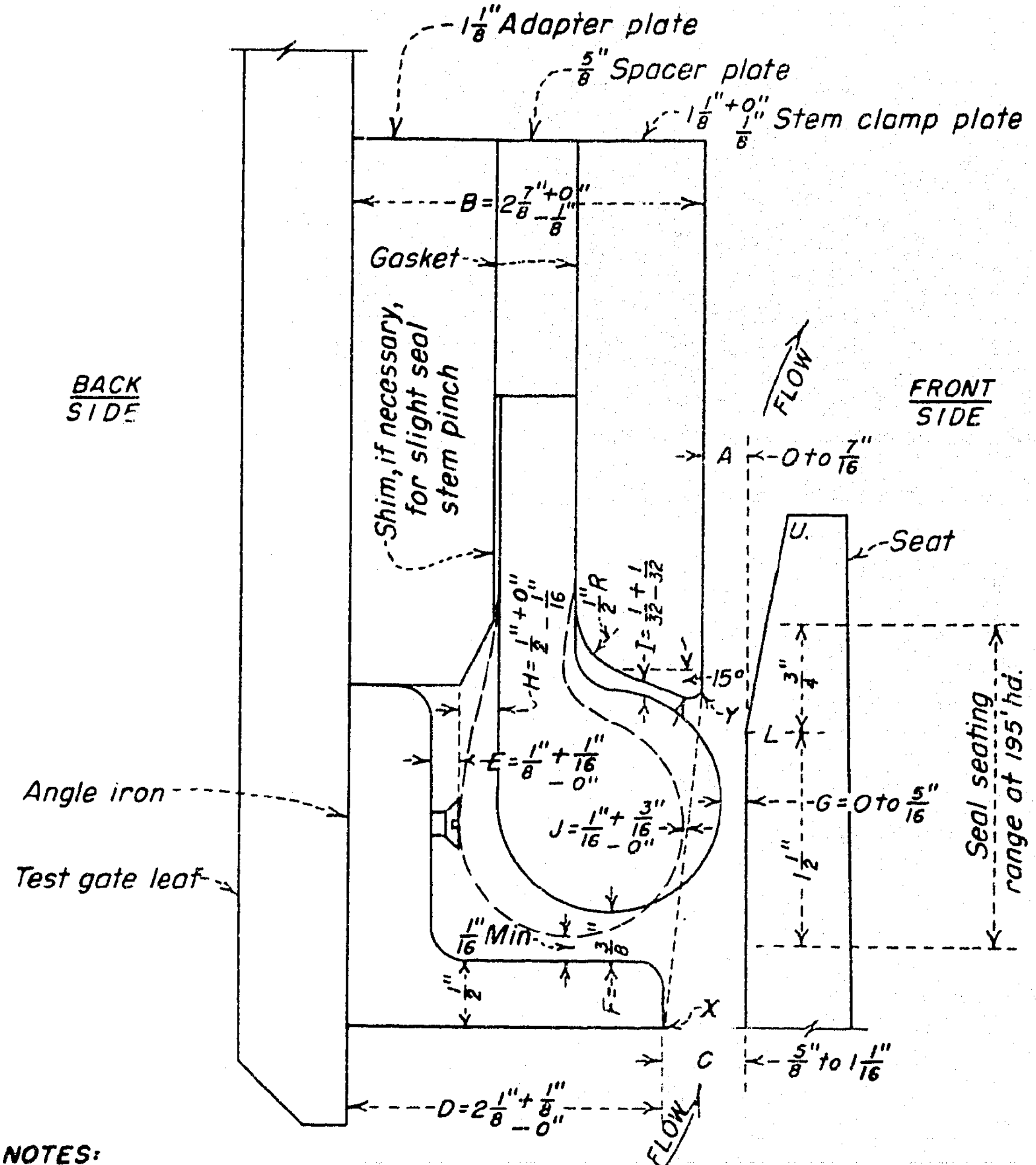
B. Solid bulb music note seal (5/32 inch seal-to-seat gap) with a 90 degree shield which retards bulb deformation and loss of contact with the spring; however, at 195 feet head, the pressure behind the seal bulb was 150 feet which is too high for dependable retraction.

HIGH HEAD GATE SEAL STUDIES

Behavior of Grand Coulee Type of Seal Assembly. With Bulb Retraction Provisions.



HIGH HEAD GATE SEAL STUDIES
TEST GATE TOP SEAT – SECTION DRAWING



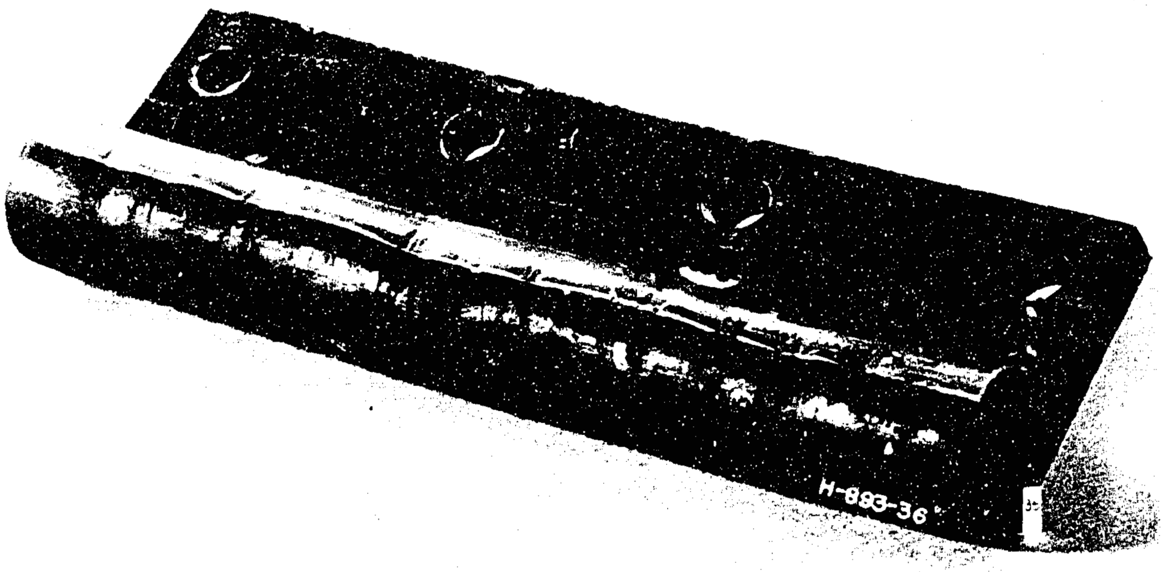
NOTES:

1. Maximum C, $1\frac{1}{16}$", goes with minimum D and maximum G, $\frac{5}{16}$". Similarly, minimum C, $\frac{5}{8}$", goes with maximum D and minimum G, zero.
2. Seal seating range on seat at 265' head (Hungry Horse) is estimated to be $\frac{3}{8}$" lower than at 195' head.
3. Test gate rate of travel equaled 0.14 inches per second.
4. Hydraulic control for retraction was edge X; for extension was edge Y.

HIGH HEAD GATE SEAL STUDIES

MUSIC NOTE SEAL ASSEMBLY. DIMENSIONS FOR AUTOMATIC RETRACTION AND EXTENSION OF BOTTOM SEAL BULB.

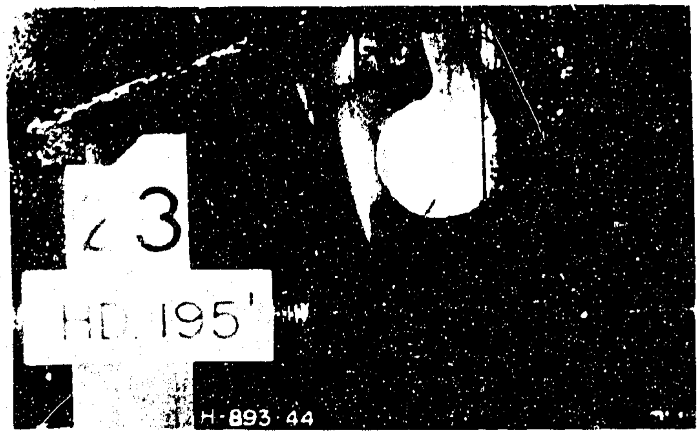
A. Beveled seal seat with brass bars soldered to face. These bars prevented complete sealing, thus decreasing water hammer.



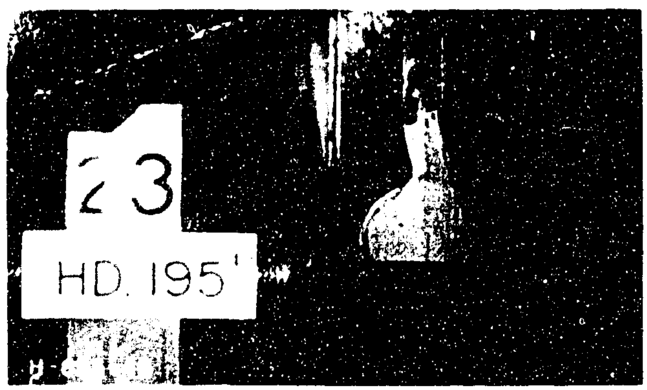
B. Solid bulb music note seal with 90 degree brass shield on bulb. This seal was used with the above seat. The damage was sustained in seating.

HIGH HEAD GATE SEAL STUDIES

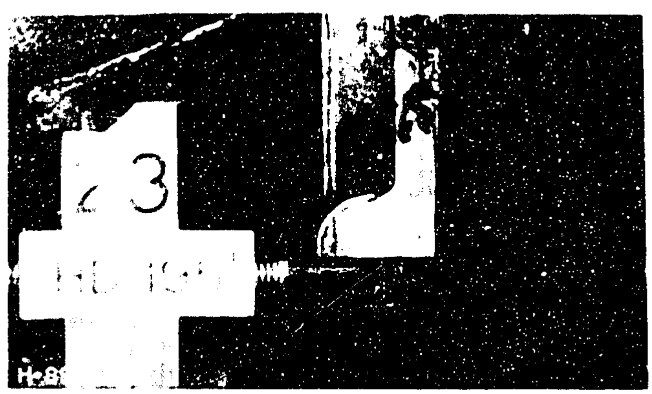
Arrangement to Reduce Water Hammer to Protect Test Equipment during Tests with Automatic Bulb Extension



A. Bulb approaching seat, control at edge of angle iron.



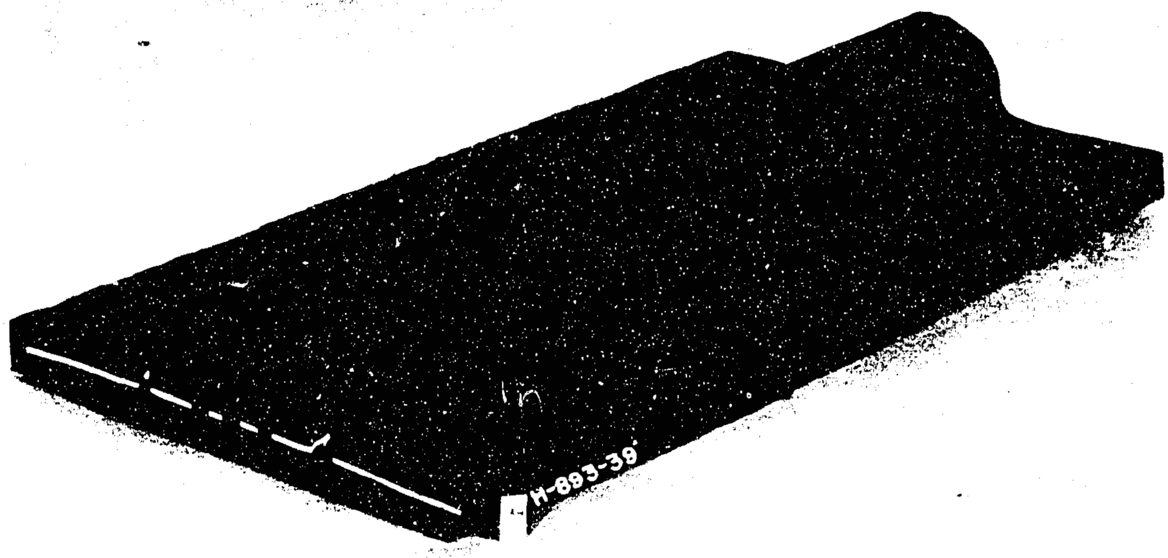
B. Bulb in position for snap-over, control at edge of stem clamp plate.



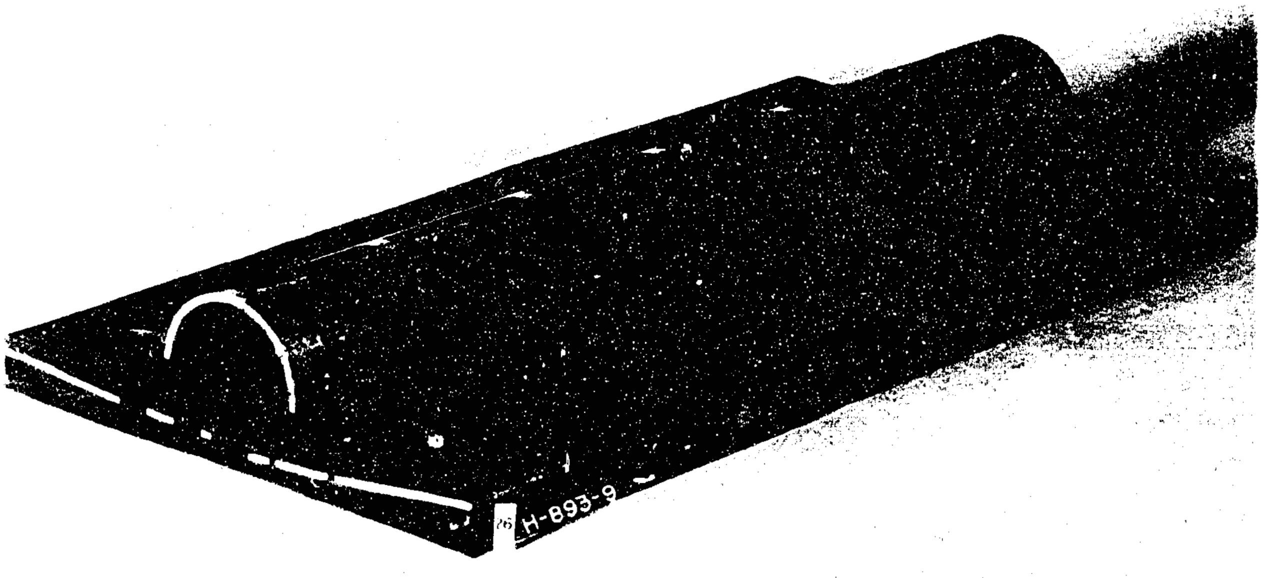
C. Bulb snapped-over onto seat.

HIGH HEAD GATE SEAL STUDIES

Photographic Sequence of Music Note Seal with Automatic Retraction and Extension of Seal Bulb--195 feet head, 1/8 inch Seal-to-Seat Gap.



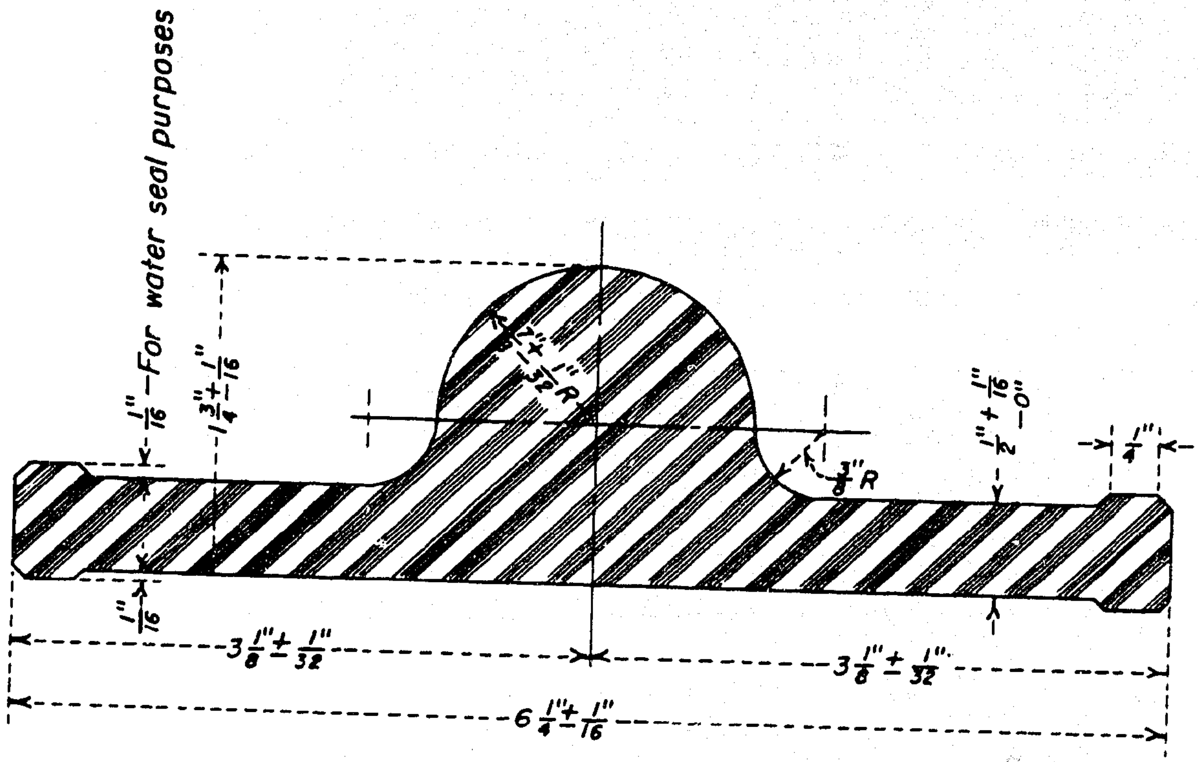
A. Seal with one piece, self centering, brass reinforcing plate in stems. The plate was centered during molding by means of the tabs shown. (See Figure 29).



B. Seal with 180 degree, slotted brass bulb shield. Two piece, brass stem reinforcing plate shifted during molding. (See Figure 27).

HIGH HEAD GATE SEAL STUDIES

Double Stem Seals with Stem Reinforcing Plates.

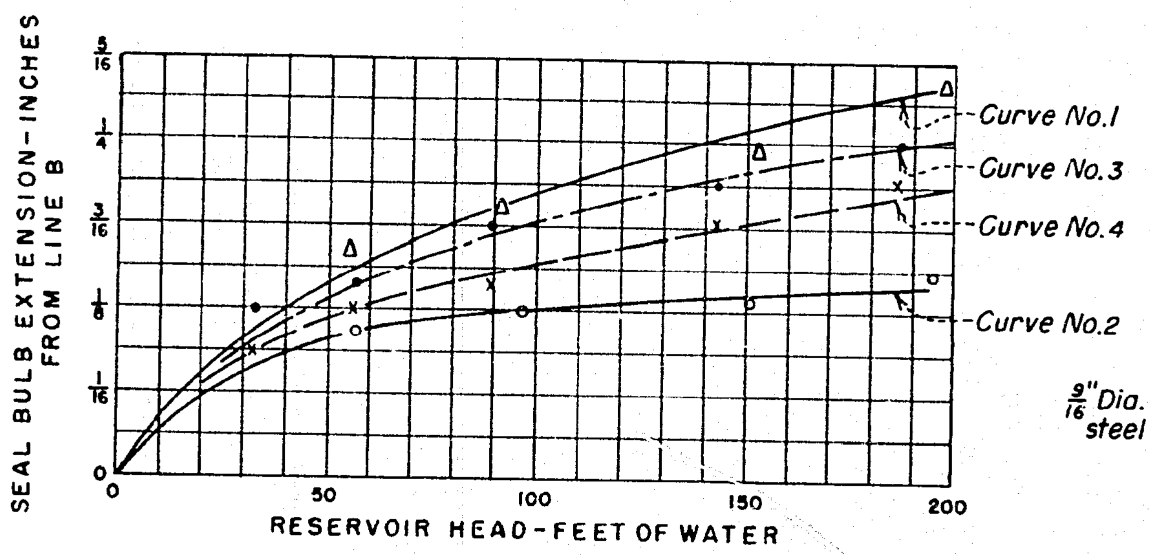


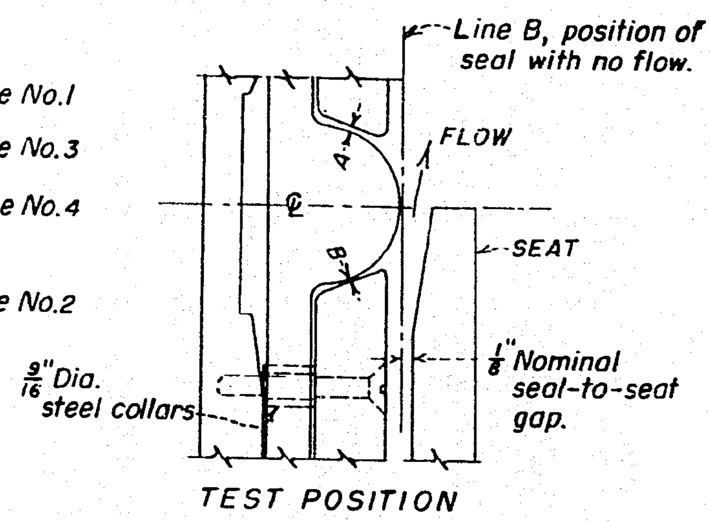
HIGH HEAD GATE SEAL STUDIES

ALL RUBBER DOUBLE STEM SEAL 222-D-14970
GRAND COULEE FIELD TESTS - OCTOBER 1950

32C

CURVE No.	SYMBOL	NO FLOW CLEARANCE A	NO FLOW CLEARANCE B	REFERENCE	REMARKS
1	Δ———Δ	$\frac{1}{16}$"	$\frac{3}{32}$"	Figure 24	No bulb shield or stem reinforcing plate Collars in stem screw holes
2	o———o	$\frac{3}{64}$"	$\frac{1}{16}$"	Figure 23 B	180° Brass shield on bulb and a two piece stem reinforcing plate. Collars in stem screw holes.
3	•- - - -•	$\frac{1}{16}$"	$\frac{1}{16}$"	Figure 23 A	No bulb shield, but with a single piece stem reinforcing plate. Collars omitted in stem screw holes to equalize clearance A and B.
4	X—— ——X	$\frac{3}{64}$"	$\frac{5}{64}$"	Figure 28	180° Brass shield on bulb integral with reinforcing plate on stem nearest outside of gate. Collars omitted for same reason as for Curve No. 3.

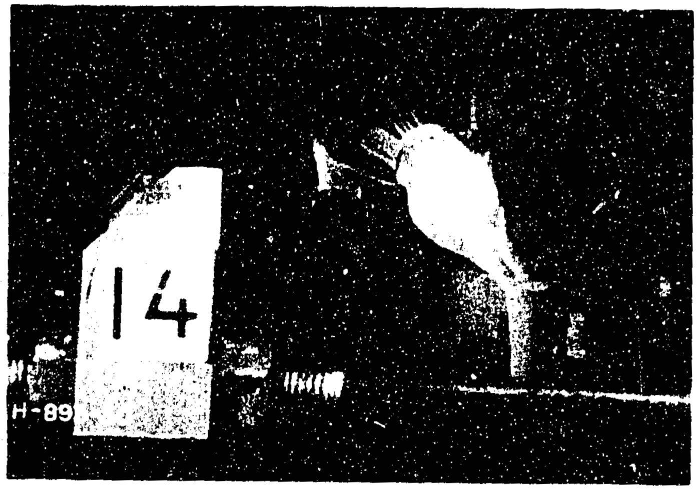




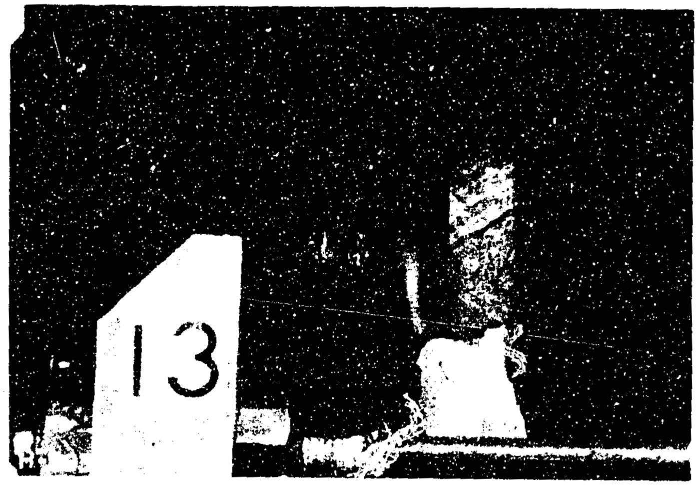
HIGH HEAD GATE SEAL STUDIES

SEAL BULB EXTENSION VERSUS RESERVOIR HEAD
DOUBLE STEM SEALS WITH STEM ATTACHING SCREWS

320



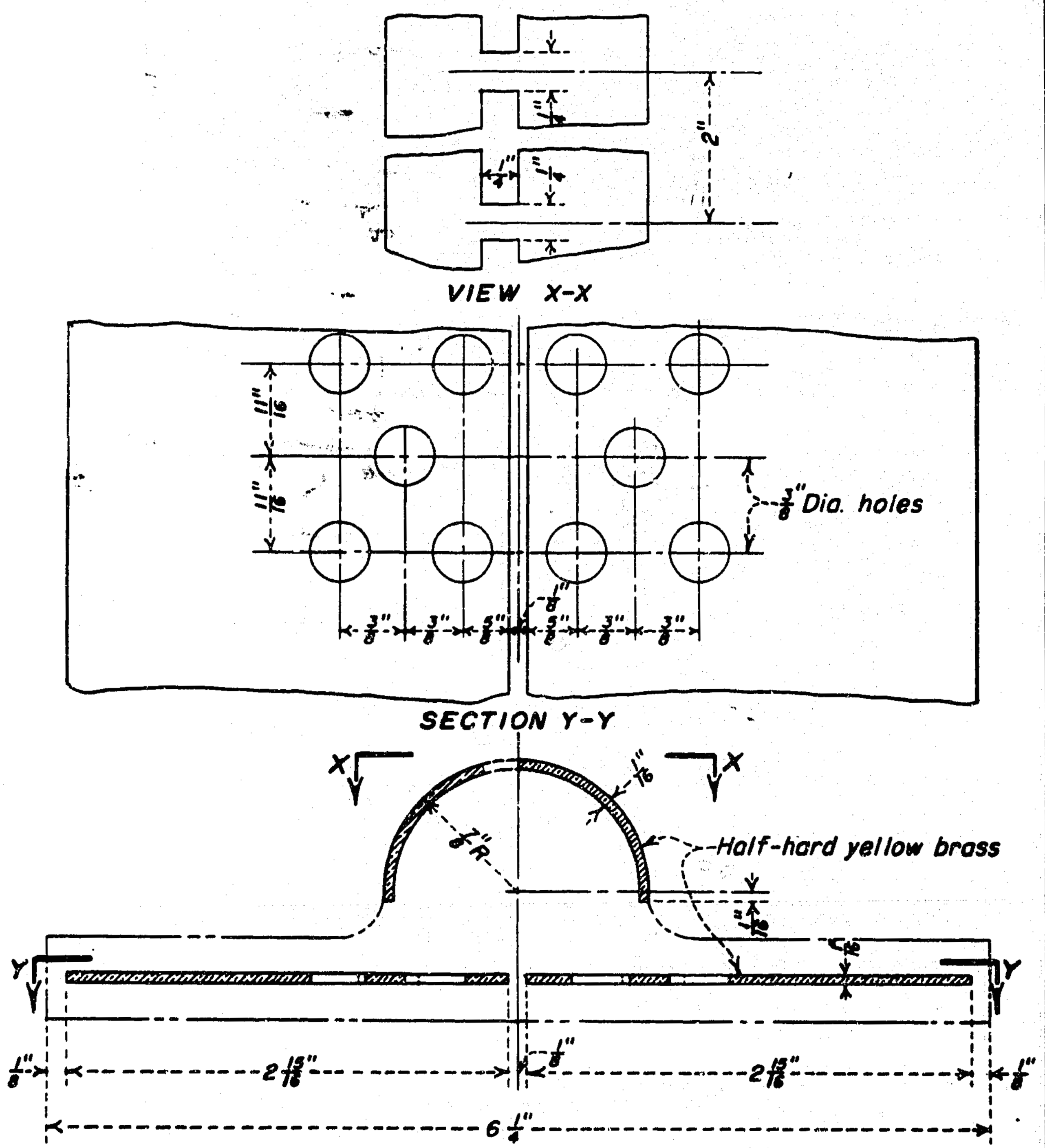
A. Unsatisfactory gate closure at zero seal-to-seat gap. Seal bulb catches on the upper corner of seat bevel.



B. Satisfactory gate closure with 1/8-inch seal-to-seat gap.

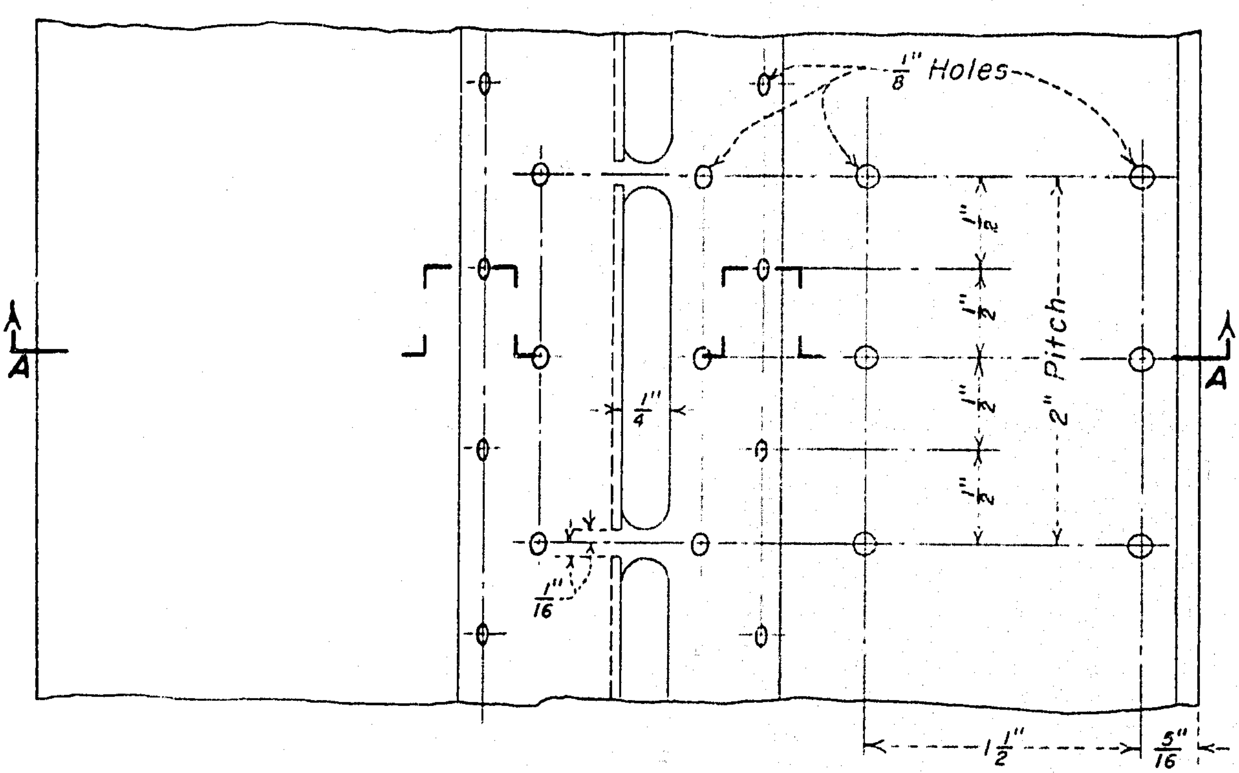
HIGH HEAD GATE SEAL STUDIES

Operation of Double Stem Seal without a Brass Shield or Stem Reinforcement. Gate Closed with Bulb Extended at 195 Head.

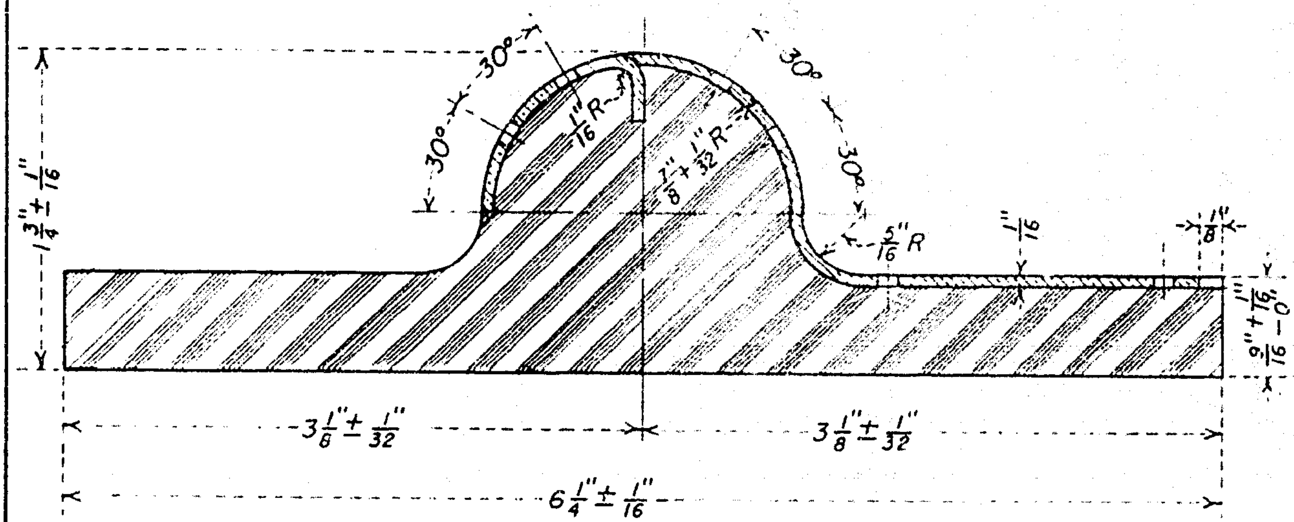


HIGH HEAD GATE SEAL STUDIES

DOUBLE STEM SEAL WITH 180 DEGREE BRASS BULB SHIELD AND TWO-PIECE, BRASS, STEM REINFORCING PLATE



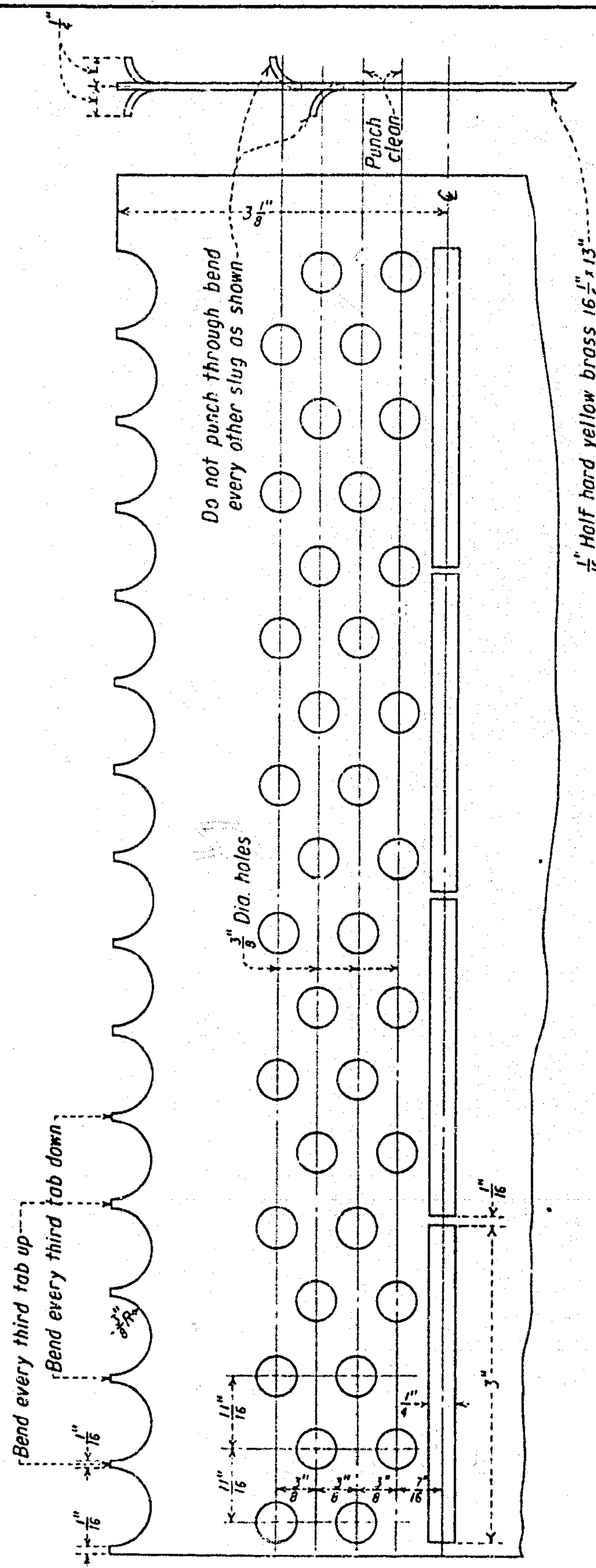
PLAN



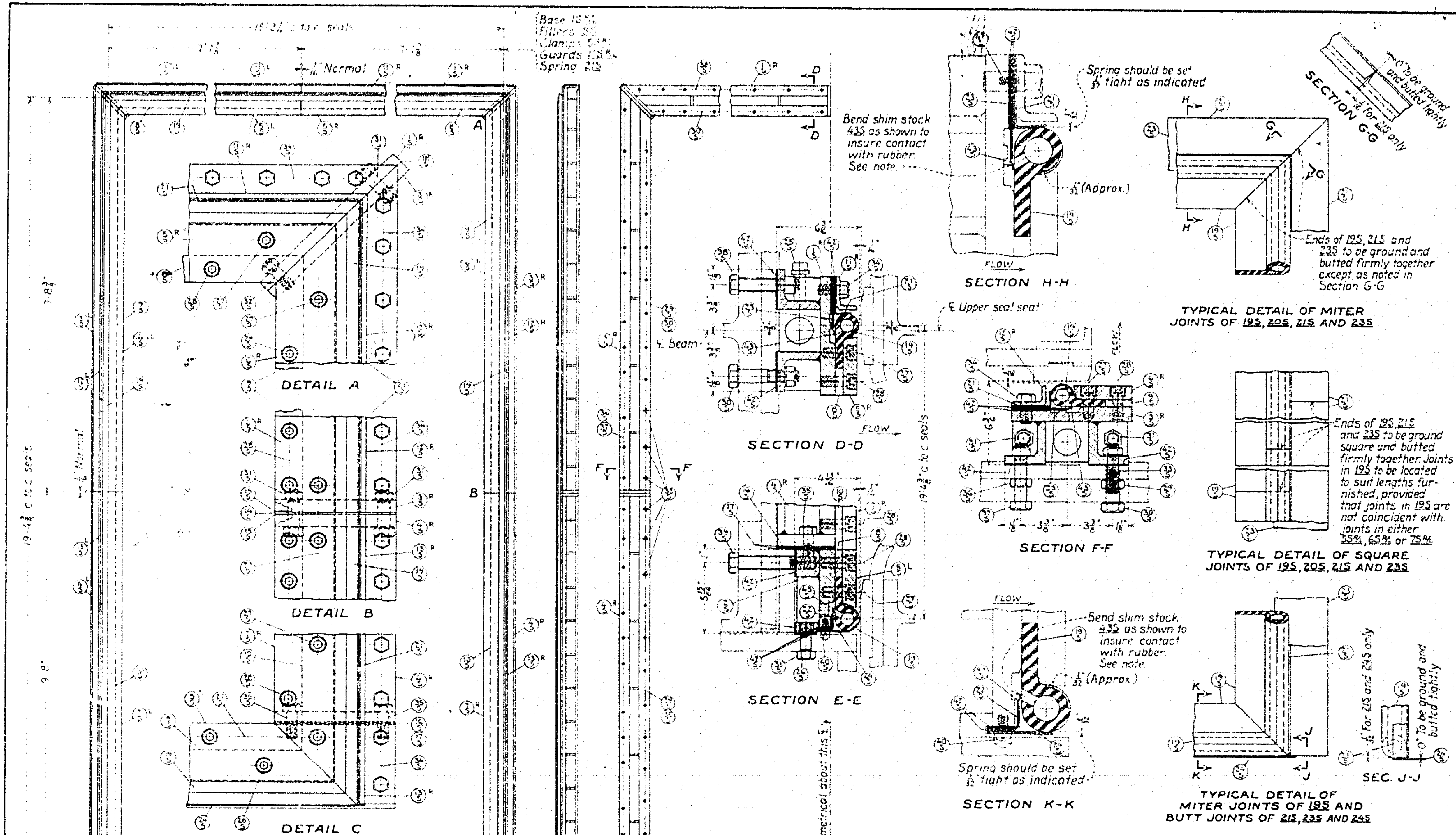
SECTION A—A

HIGH HEAD GATE SEAL STUDIES

DOUBLE STEM SEAL WITH INTEGRAL BULB-STEM BRASS PLATE



HIGH HEAD GATE SEAL STUDIES
DOUBLE STEM SEAL SELF-CENTERING STEM REINFORCING PLATE



Bases 35R/L and 45R/L
Fillers 9S and 10S
Clamps 65R/L and 75R/L
Guards 125R/L and 135R/L
Spring 21S

DOWNSTREAM ELEVATION — SIDE ELEVATION — UPSTREAM ELEVATION

SEAL ASSEMBLY
ASSEMBLE ONE-11195-S

TYPICAL DETAIL OF MITER JOINTS OF 19S AND BUTT JOINTS OF 21S, 23S AND 24S

LIST OF PARTS - SEALS FOR ONE GATE

DRAWING NUMBER	PART NO.	NO. REQ'D	DESCRIPTION	MATERIAL CLASSIFICATION	MAT'L REF. NO.	USED WITH
214-D-11205	1SR	1	Top seal base	Steel	B55	
"	1SL	1	Top seal base	Steel	B55	
214-D-11206	2S	1	Bottom seal base	Steel	B55	
214-D-11207	3SR	1	Vertical seal base	Steel	B55	
"	3SL	1	Vertical seal base	Steel	B55	
"	4SR	1	Vertical seal base	Steel	B55	
"	4SL	1	Vertical seal base	Steel	B55	
214-D-11208	5SR	1	Horizontal clamp	Steel	B55	
"	5SL	1	Horizontal clamp	Steel	B55	
"	6SR	1	Vertical clamp	Steel	B55	
"	6SL	1	Vertical clamp	Steel	B55	
"	7SR	1	Vertical clamp	Steel	B55	
"	7SL	1	Vertical clamp	Steel	B55	
"	8S	4	Horizontal filler	Steel	B55	
"	9S	2	Vertical filler	Steel	B55	
"	10S	2	Vertical filler	Steel	B55	
"	11SR	1	Horizontal guard	Steel	B55	
"	11SL	1	Horizontal guard	Steel	B55	
"	12SR	1	Vertical guard	Steel	B55	
"	12SL	1	Vertical guard	Steel	B55	
"	13SR	1	Vertical guard	Steel	B55	
"	13SL	1	Vertical guard	Steel	B55	
"	14S	3	Shim (laminated)	Brass	†	
"	15S	6	Gasket	GARLOCK No. 681 OR EQUIVALENT		
"	16S	2	Shim (laminated)	Brass	†	
"	17S	2	Gasket	GARLOCK No. 681 OR EQUIVALENT		
"	18S	2	Gasket	GARLOCK No. 681 OR EQUIVALENT		
"	19S	△72LF	Seal	RUBBER AND BRASS	†	
"	21S	54 LF	Spring	STEEL OR BRASS	†	
"	22S	16 LF	Retainer	Steel	†	
"	23S	56 LF	Retainer	Steel	†	
"	24S	16 LF	Spring	STEEL OR BRASS	†	
"	25S	2	Air vent	Steel	†	1SR/L
"	26S	10+2	Dowel	STEEL OR NI.CU. ALLOY	C75 OR F19	3, 2S
"	27S	106+7	Socket head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	1SR/L, 2S, 3SR/L, 4SR/L, 5SR/L, 6SR/L, 7SR/L
"	28S	104+7	Socket head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	1SR/L, 2S, 3SR/L, 4SR/L, 5SR/L, 6SR/L, 7SR/L
"	29S	12+2	Special bolt with nut	STEEL OR NI.CU. ALLOY	C75 OR F19	1,2,3,3R/L,4SR/L
"	30S	40+4	Special bolt with nut	STEEL OR NI.CU. ALLOY	C75 OR F19	1,2,3,1SR/L,3SR/L,4SR/L
"	31S	8+2	Special bolt with nut	STEEL OR NI.CU. ALLOY	C75 OR F19	1SR/L, 3SR/L, 4SR/L
"	32S	2+2	Stud with nut	STEEL OR NI.CU. ALLOY	C75 OR F19	1SR/L, 3SR/L
"	33S	12+2	Stud with nut	STEEL OR NI.CU. ALLOY	C75 OR F19	2, 3SR/L, 4SR/L
No detail	†34S	68+10	3/4"x1 1/4" Hex head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	1SR/L, 3SR/L, 4SR/L, 11SR/L, 12SR/L, 13SR/L
"	†35S	26+3	3/4"x 2" Hex head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	3, 2S, 4SR/L
"	†36S	12+2	[illegible] Hex head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	1,2,3,3SR/L, 4SR/L
"	†37S	34+3	[illegible]x4 1/4" Hex head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	1,2,3,3SR/L, 4SR/L
"	†38S	22+2	[illegible] Hex hd bolt with sq nut	STEEL OR NI.CU. ALLOY	C75 OR F19	1, 1S
"	†39S	22+2	1"x5 1/2" Hex head cap screw	STEEL OR NI.CU. ALLOY	C75 OR F19	3, 2S
"	†40S	42+4	3/8"x 3/4" Round head screw	STEEL OR NI.CU. ALLOY	C75 OR F19	2S, 22S, 24S
"	†41S	12+2	1/4"x 1/2" Round head screw	Steel	†	1SR/L, 3SR/L, 4SR/L, 23S
"	†42S	*	Gasket 1/16" thick	GARLOCK No. 681 OR EQUIVALENT		
"	†43S	74 LF	2 1/4"x .003" Shim stock	STEEL OR BRASS	†	
X-D-311	†44S	2	3/4" Drill for rubber	Steel	†	19S
"	†45S	2	5/8" Drill for rubber	Steel	†	19S

* Furnish in rolls or sheets in sufficient amount to cover areas under bases 1SR/L, 2S, 3SR/L, 4SR/L retainers 22S, 23S and ship 43S indicated in sections D-D, E-E, F-F, H-H and K-K.

† Where materials are specified on the drawings, but are not further covered by detailed specifications, the contractor shall furnish high class commercial grades of materials that are satisfactory to the contracting officer

† Use 11204 as prefix of the mark number.

△ Furnished by the Government.

NOTES

See specifications for marking

Parts 22S, 23S and 43S are provided to maintain booster pressure required in removing hemispherical bulkhead in penstock, (see Dwg. 214-D-9367) and are to be removed at earliest opportunity after hemispherical bulkhead is removed.

Part 41S is provided for convenient holding of parts 23S and 43S. Provide holes in 23S for 41S and in 21S to clear heads of 41S.

Where a mark number covers more than one shipping length, the contractor shall add suitable subscripts to the mark number to properly identify each length.

REFERENCE DRAWINGS

15'x19.05' COASTER GATE LEAF - ASSEMBLY - LIST OF PARTS 214-D-11195
15'x19.05' COASTER GATE FRAME - ASSEMBLY 214-D-2299
15'x19.05' COASTER GATE LEAF - PRESSURE BOOSTING SYSTEM 214-D-9367
ALLOWANCES AND TOLERANCES FOR METAL FITS X-D-893

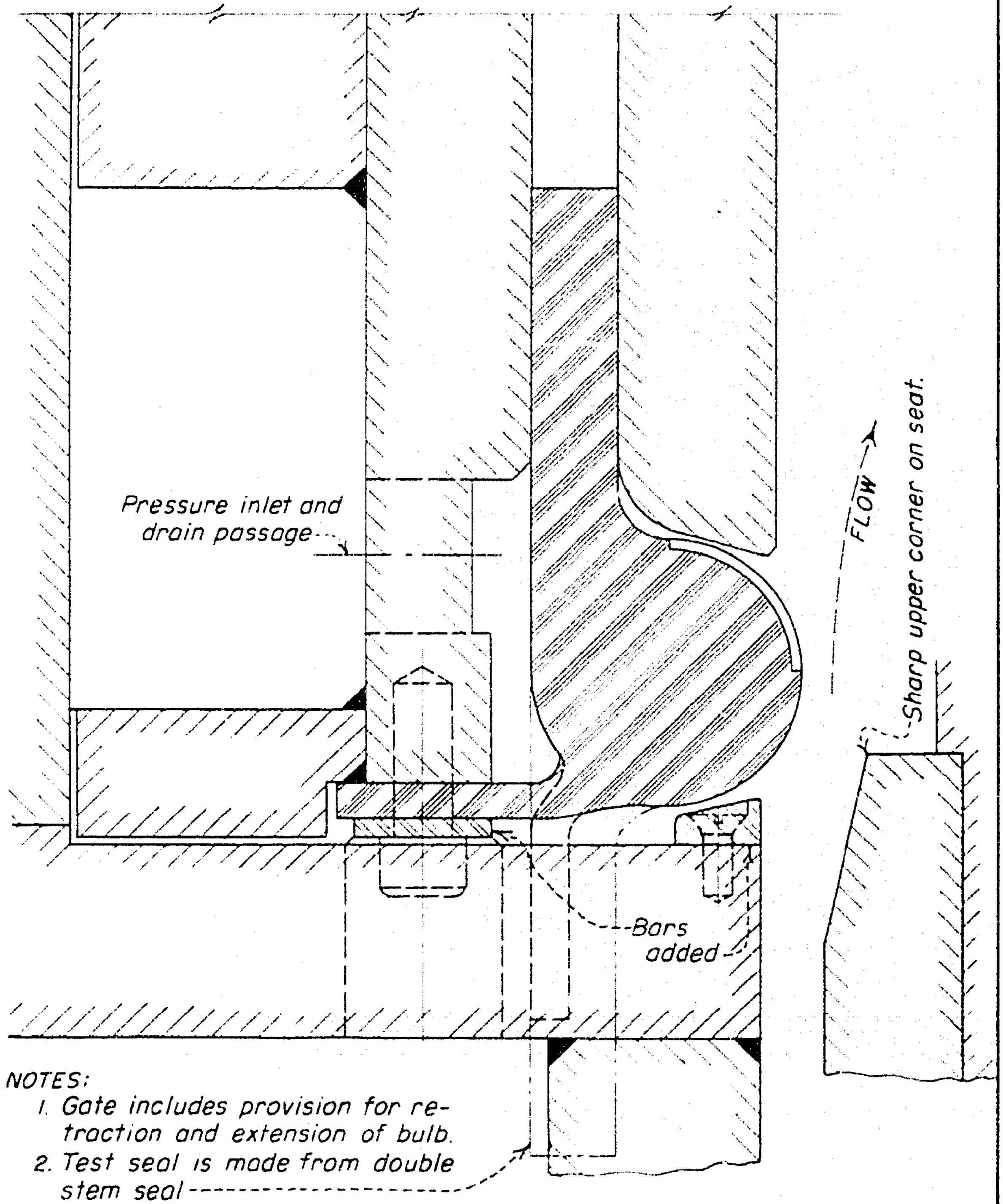
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT-CALIFORNIA
KENNETT DIVISION

SHASTA DAM

MAIN UNIT PENSTOCKS
15'x 19.05' COASTER GATE LEAF
SEALS
ASSEMBLY - LIST OF PART
GATES 3 TO 5

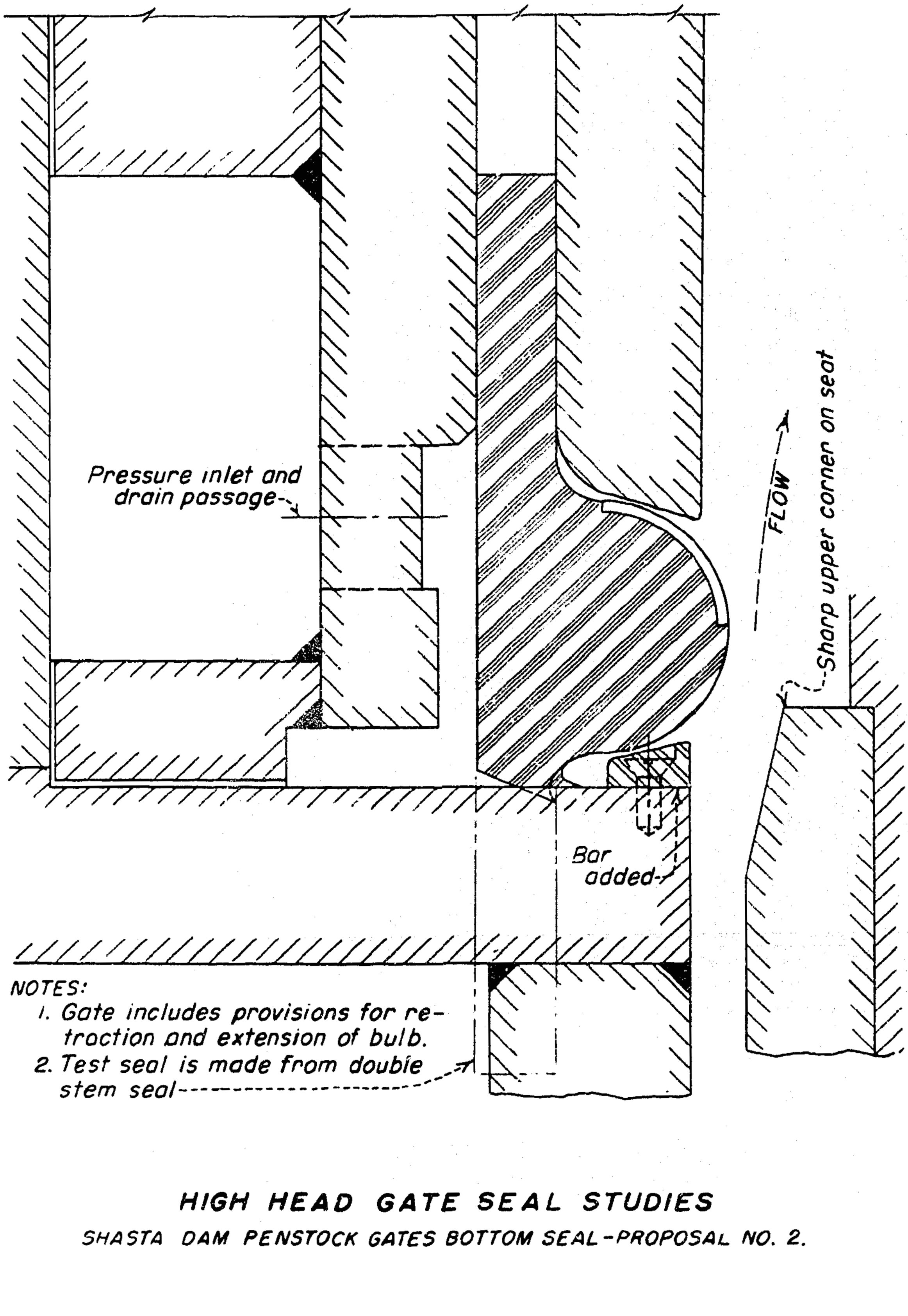
DRAWN O.M.S. — SUBMITTED L. N. McClellan
TRACED H.R.S. — RECOMMENDED J. L. Savage
CHECKED — APPROVED Walker R. Young

DENVER, COLORADO, NOV. 6, 1942 SHEET 10 OF 20 — 214-D-11204



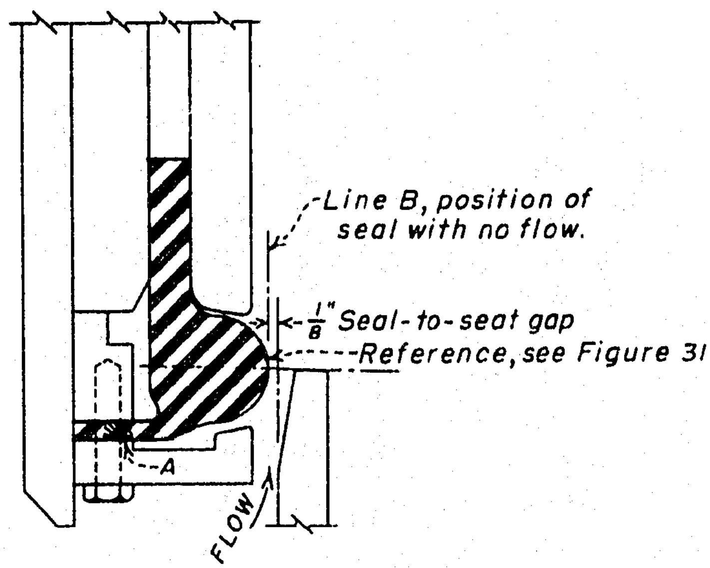
HIGH HEAD GATE SEAL STUDIES

SHASTA DAM PENSTOCK GATES BOTTOM SEAL—PROPOSAL NO. 1.

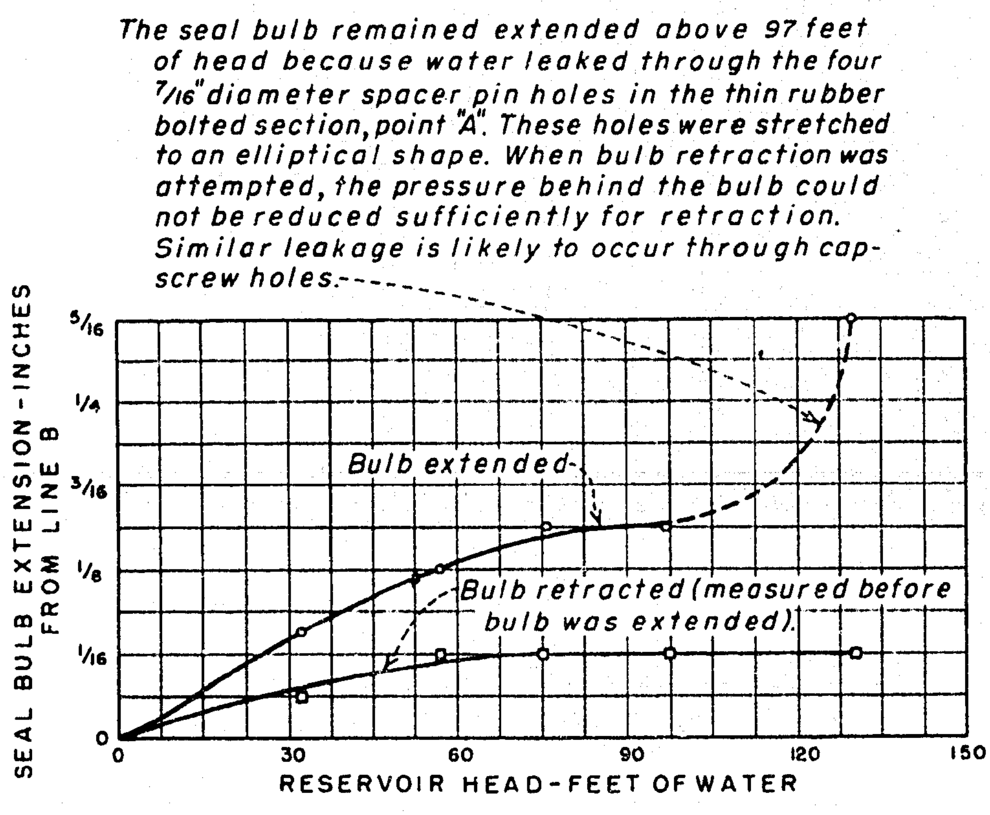


HIGH HEAD GATE SEAL STUDIES

SHASTA DAM PENSTOCK GATES BOTTOM SEAL-PROPOSAL NO. 2.

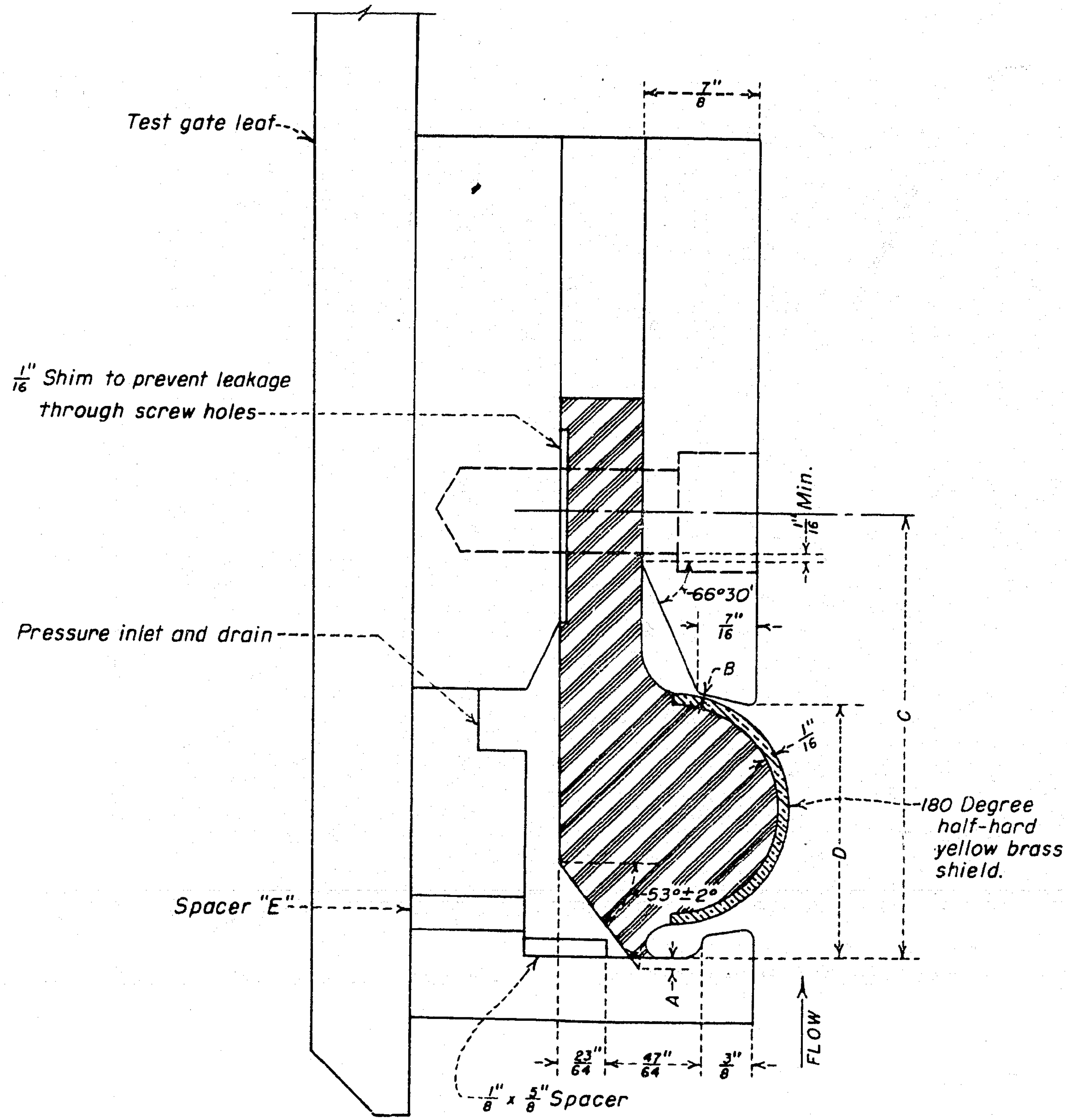


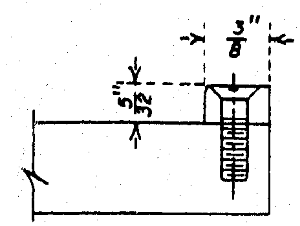
TEST POSITION



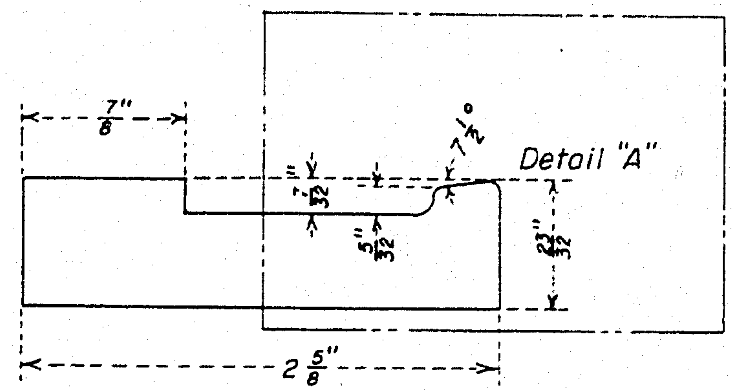
HIGH HEAD GATE SEAL STUDIES

SEAL BULB EXTENSION VERSUS RESERVOIR HEAD
SHASTA PENSTOCK GATES BOTTOM SEAL - PROPOSAL No. 1.





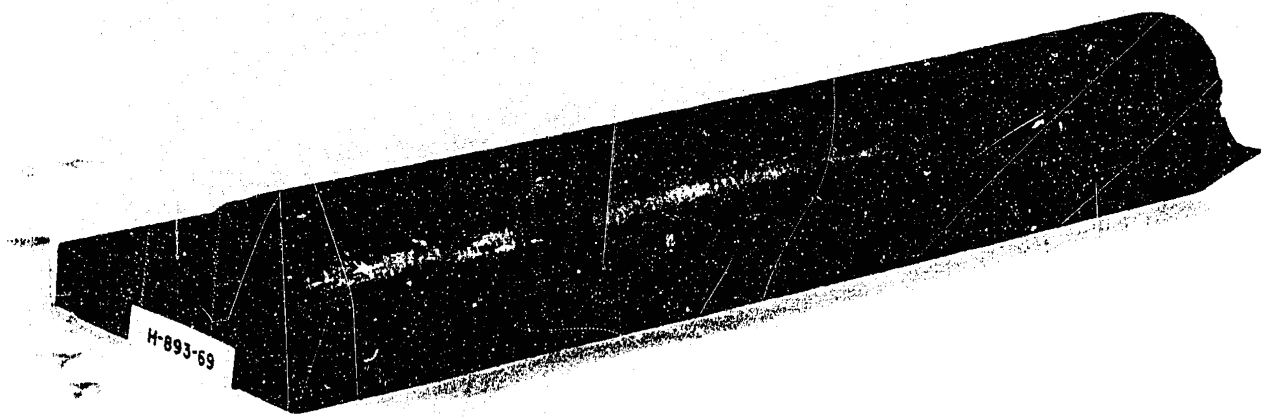
DETAIL A
SUITABLE FIELD DESIGN



	DIMENSION				D on Figure 32
Spacer "E"	A	B	C	D	
$\frac{1}{4}$"	$\frac{3}{32}$"	0"	$3\frac{15}{32}$"	$1\frac{15}{16}$"	$1\frac{27}{32}$"
$\frac{1}{8}$"	$\frac{7}{32}$"	0"	$3\frac{11}{32}$"	$1\frac{13}{16}$"	$1\frac{27}{32}$"

NOTE: It is important that deflection "A" of the seal stub be adhered to in field assembly.

HIGH HEAD GATE SEAL STUDIES
SHASTA PENSTOCK GATES-RECOMMENDED BOTTOM SEAL DESIGN

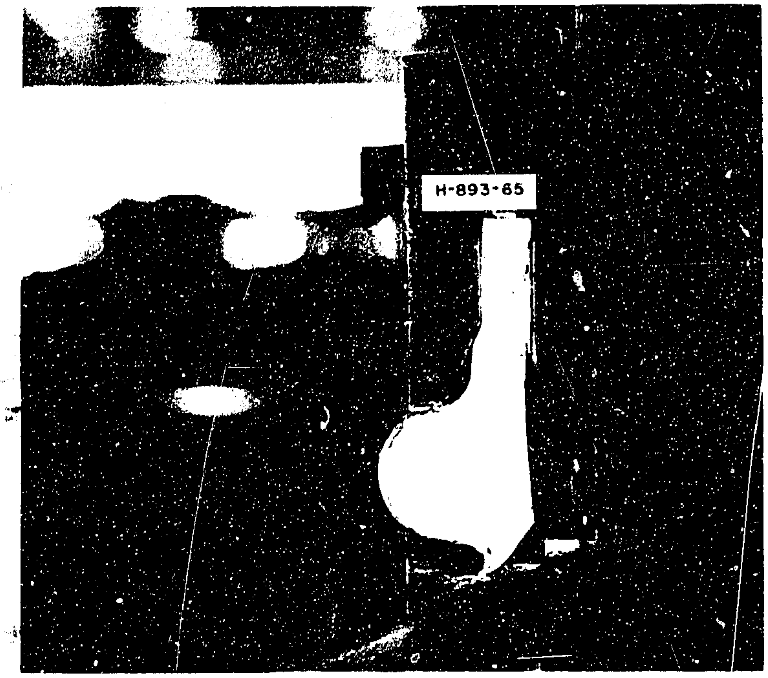


A. Recommended bottom seal with 180 degree, slotted brass shield.

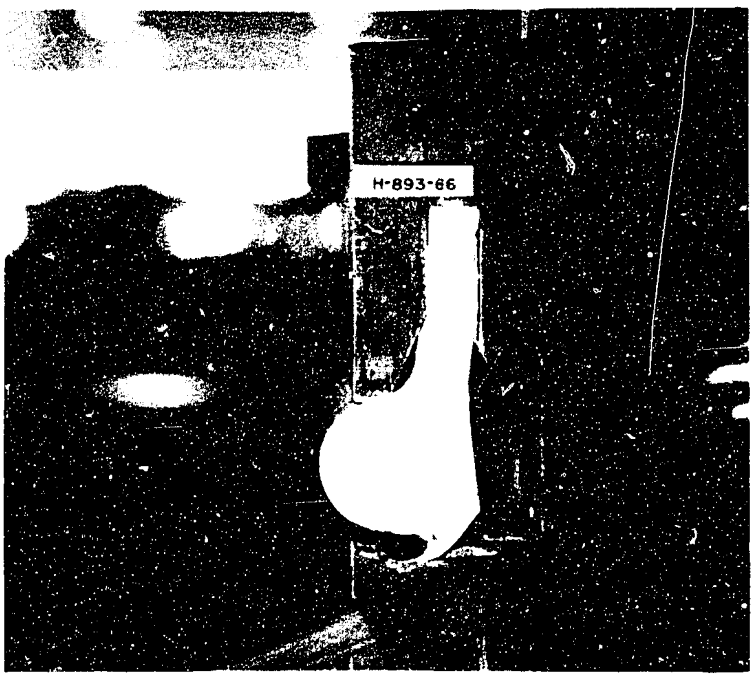
B. Bulb raised above seat at 195 feet head. The bulb showed no tendency to blowout with the minimum compression of beveled stem, 3/32 inch. This test simulated a failure in the bulb retraction system.

HIGH HEAD GATE SEAL STUDIES

Section and Operation View of Recommended Bottom Seal Shasta Penstock Gates.



A. Assembly with minimum compression, 3/32 inch, of beveled stem. Seal end painted white.

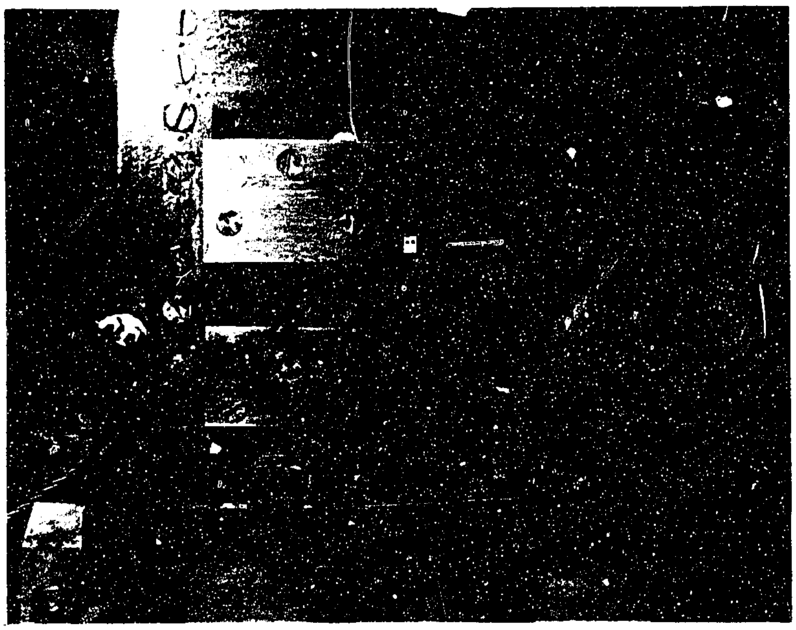


B. Assembly with maximum compression, 7/32 inch, of beveled stem. Seal end painted white.

HIGH HEAD GATE SEAL STUDIES

Assembly Views of Recommended Bottom Seal Shasta Penstock Gates.

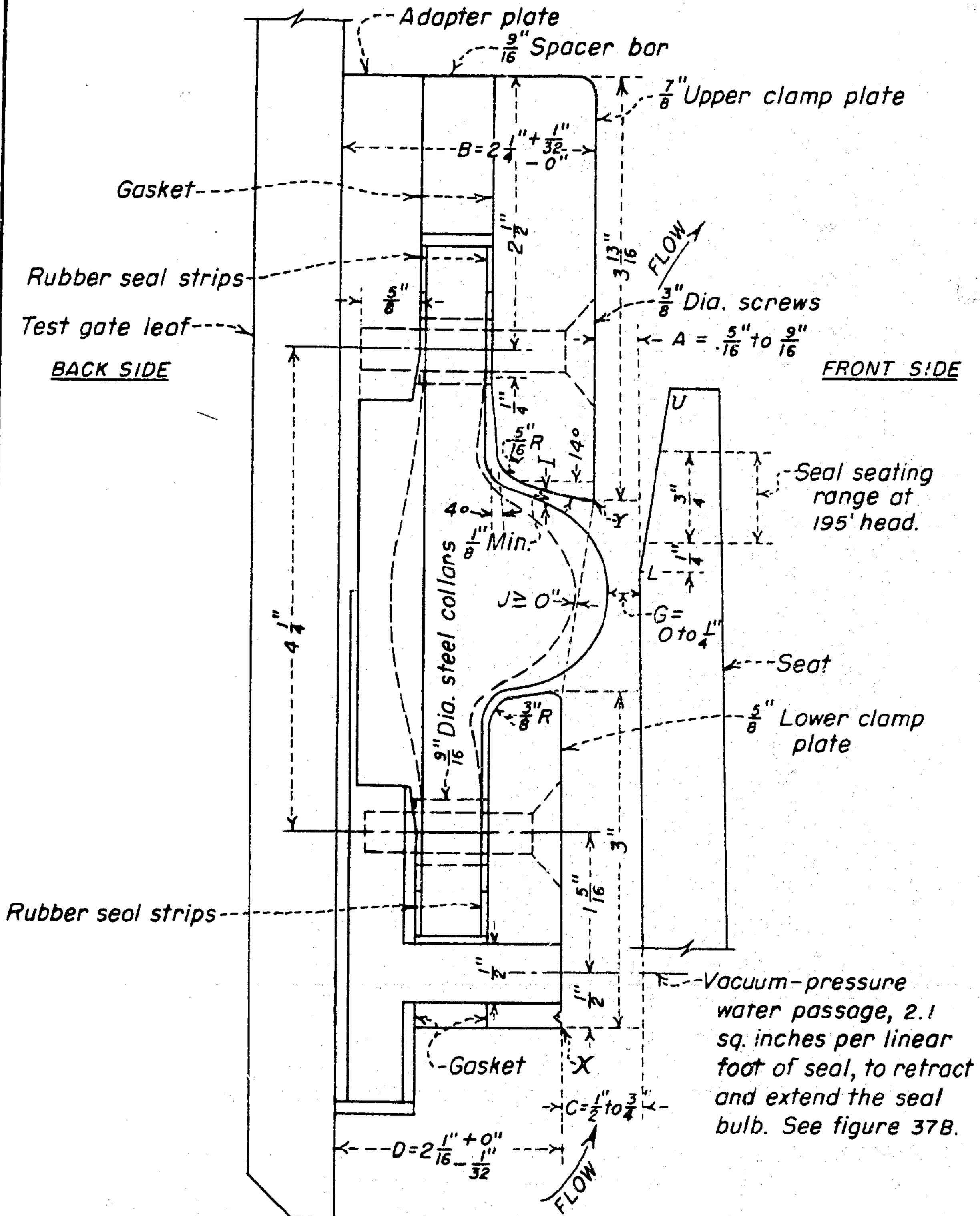
A. Side view of seal assembly showing penstock entrance transition section.



B. View showing vacuum-pressure ports in lower seal stem clamp plate.

HIGH HEAD GATE SEAL STUDIES

Double Stem Seal with Stem Attaching Screws Assembled for Automatic Retraction and Extension of Seal Bulb



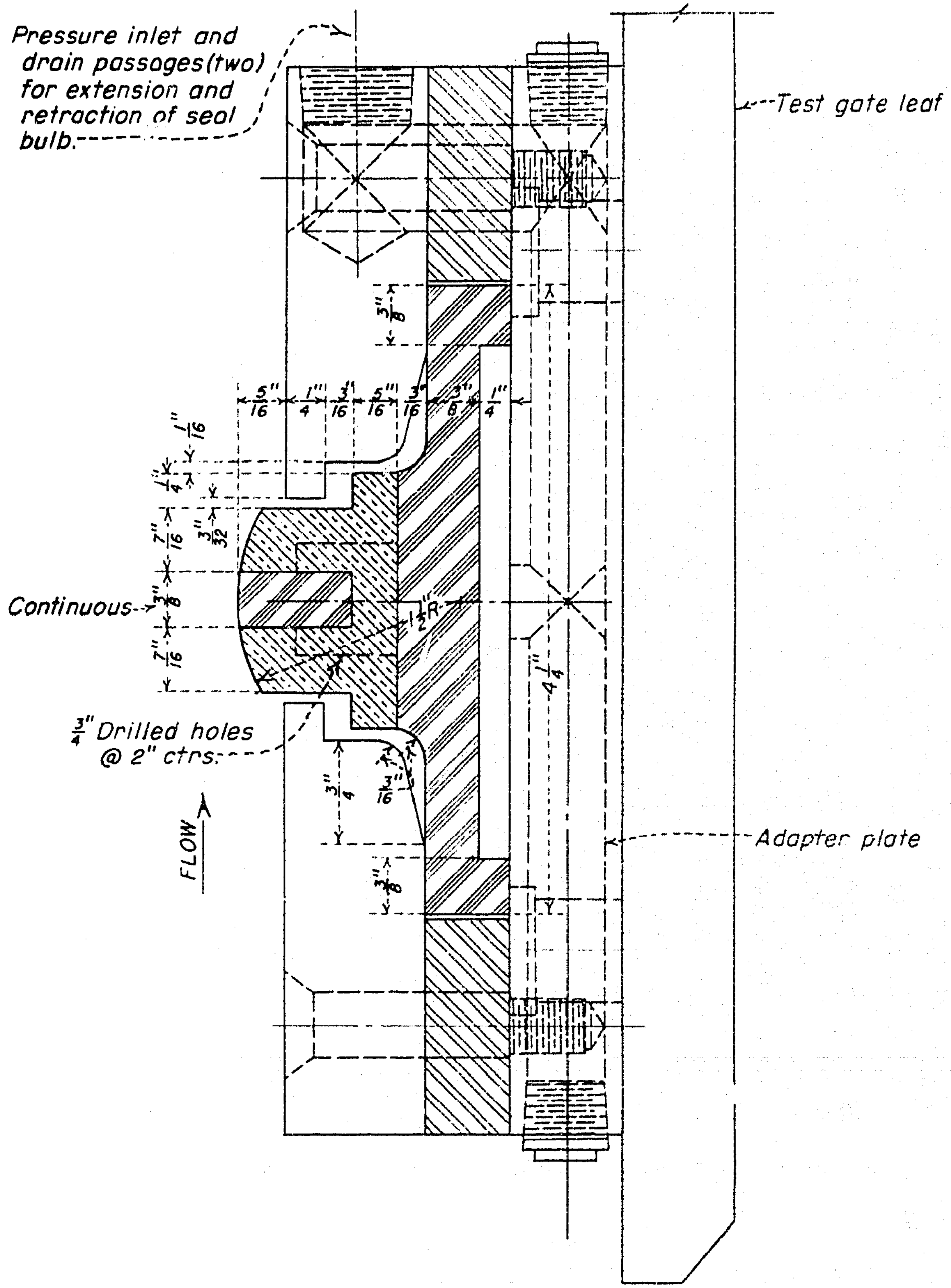
NOTES:

1. Seal seating range on seat at 265' head (Hungry Horse) is estimated to be $\frac{1}{4}$" lower than at 195' head.
2. Test gate rate of travel equaled 0.14 inches per second.
3. Hydraulic control for retraction was edge X; for extension was edge Y.

HIGH HEAD GATE SEAL STUDIES

DOUBLE STEM SEAL ASSEMBLY. DIMENSIONS FOR AUTOMATIC RETRACTION AND EXTENSION OF BOTTOM SEAL BULB.

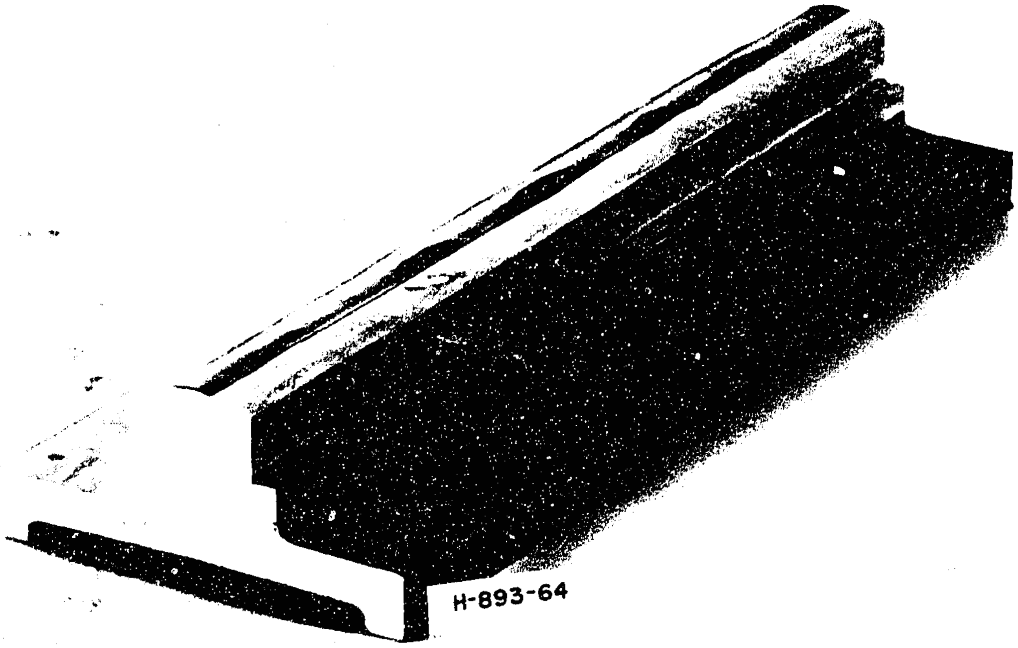
320



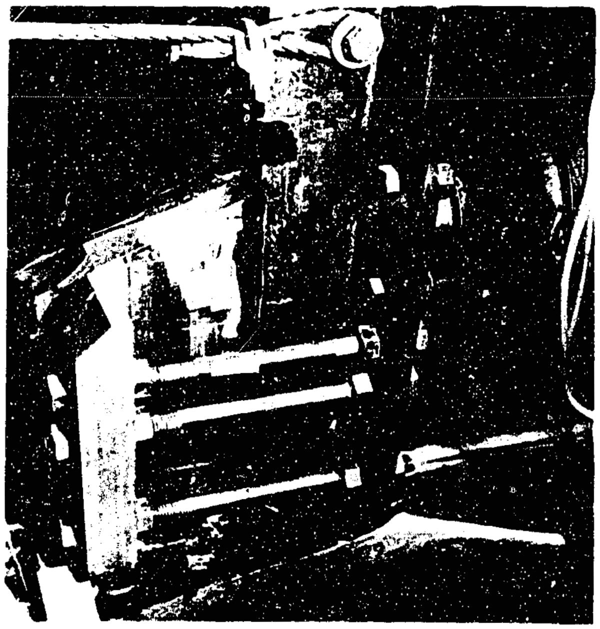
HIGH HEAD GATE SEAL STUDIES

DOUBLE STEM SEAL WITHOUT STEM ATTACHING SCREWS — DESIGN NO. 1

TEST GATE ASSEMBLY



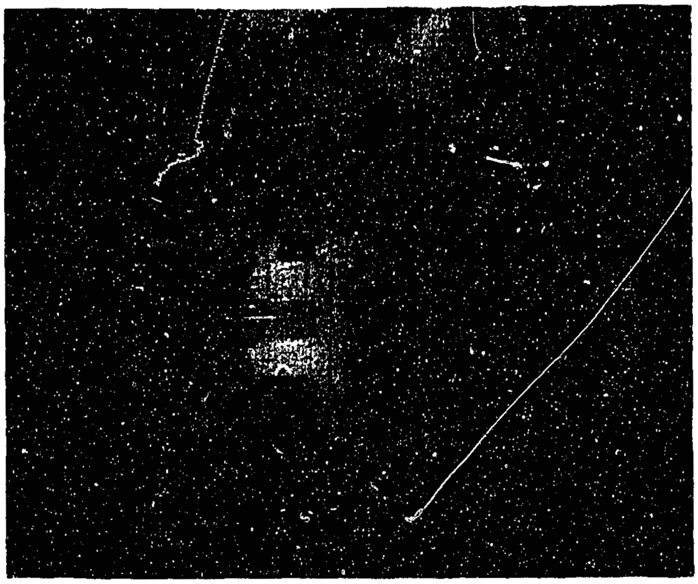
A. Twelve-inch test section of seal. End painted white.



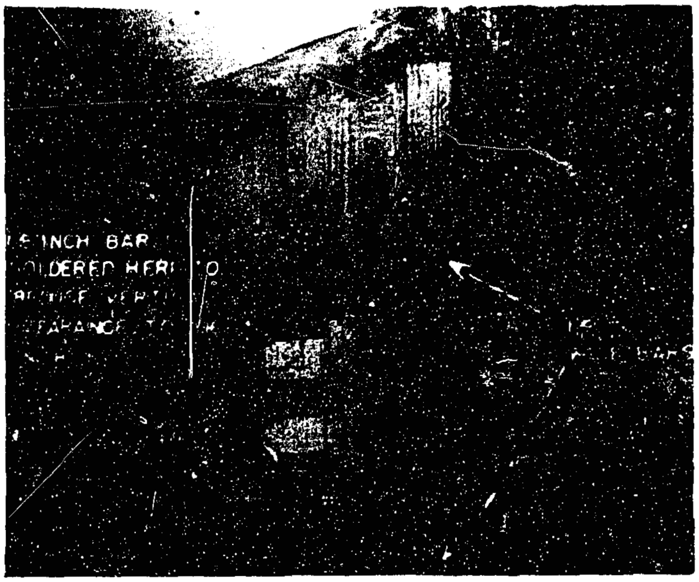
B. Seal retracted at 120 feet head--showing buckled stem and twist of bulb section. 1/8 inch seal-to-seat gap.

HIGH HEAD GATE SEAL STUDIES

Photographs of the Double Stem Seal without Stem Attaching Screws--Design No. 1.



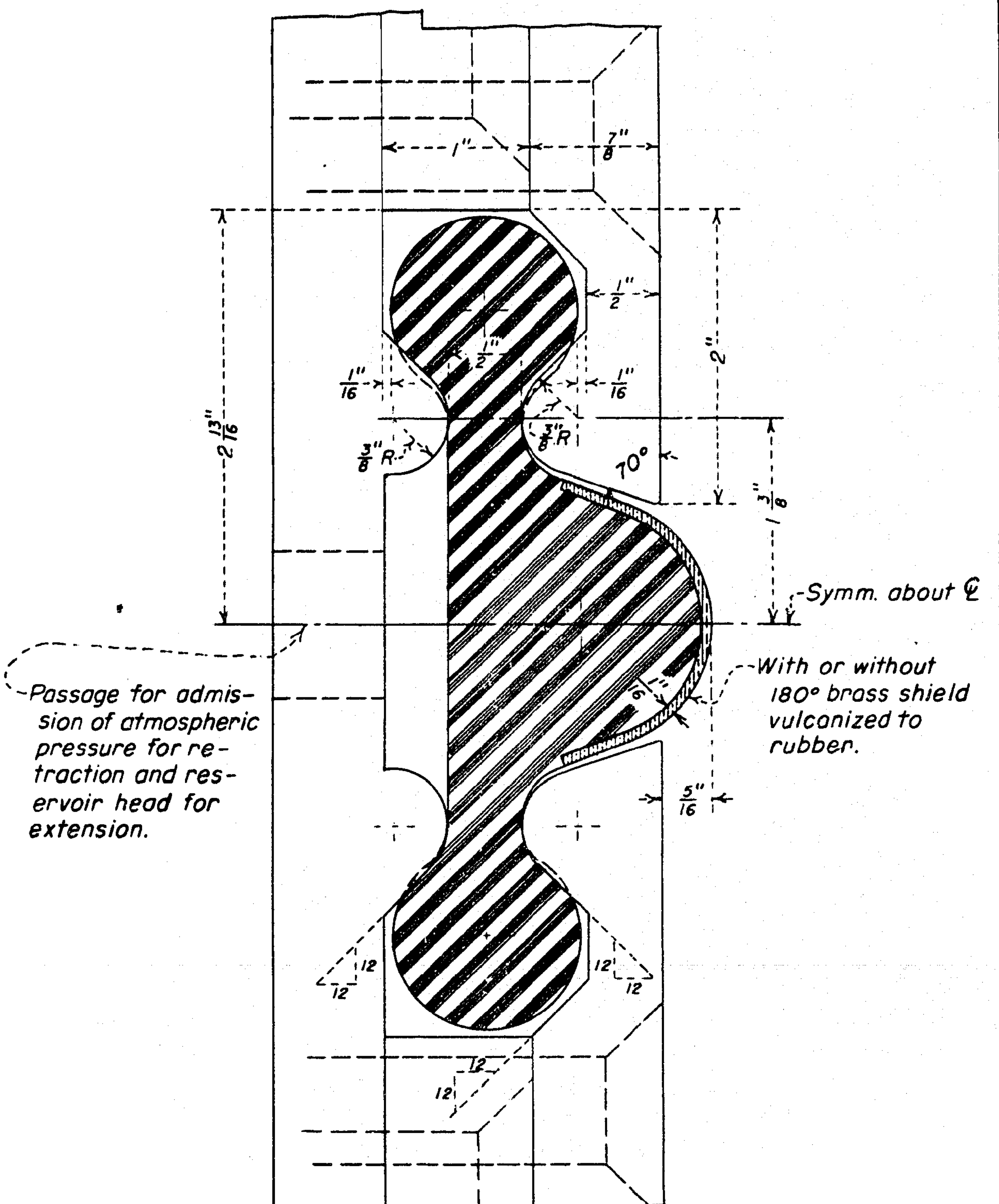
A. Seal bulb extended at 120 feet head.



B. Seal in retracted position at 195 feet head with bars in place, intended to stop stem buckling.

HIGH HEAD GATE SEAL STUDIES.

Operation of Double Stem Seal without Stem Attaching Screws--
Design No. 1; 1/8-inch Seal-to-Seat Gap.

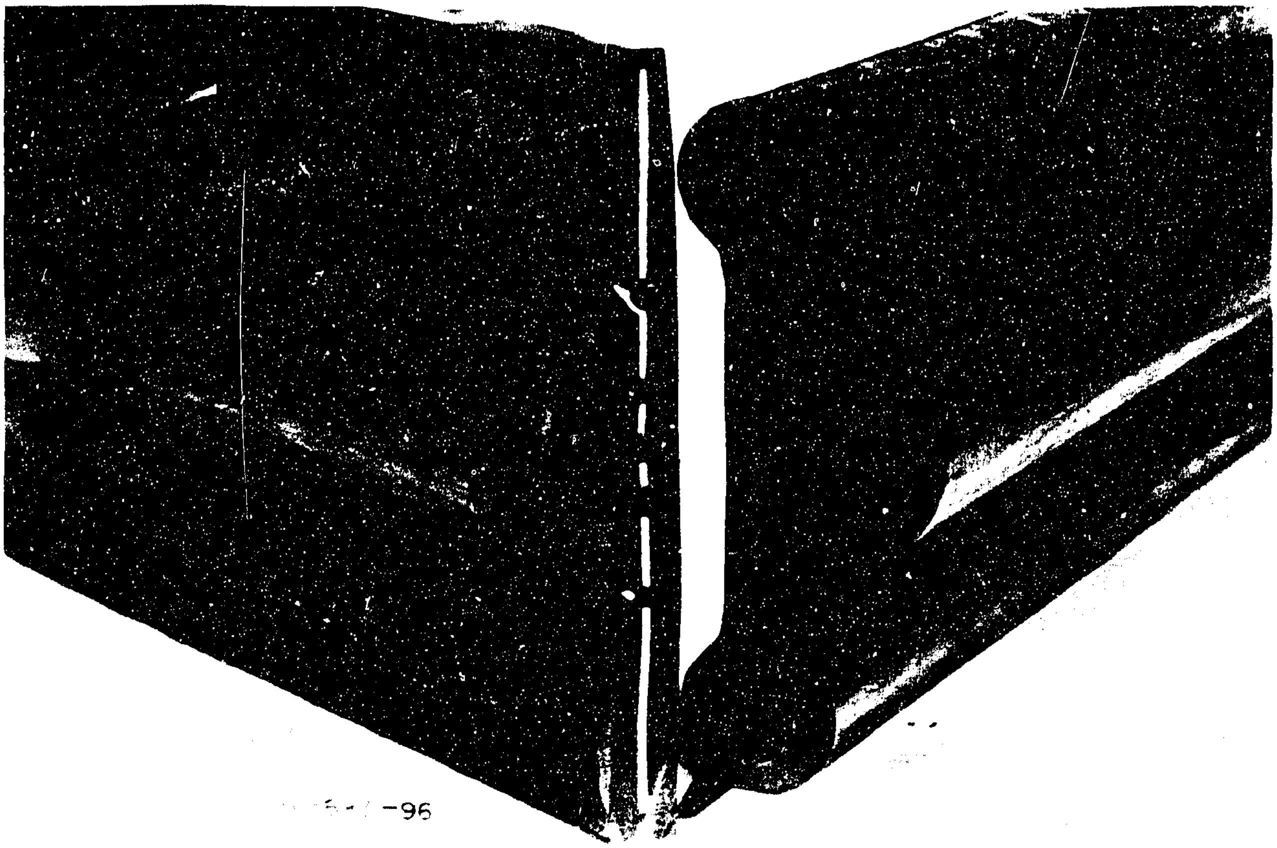


HIGH HEAD GATE SEAL STUDIES

DOUBLE STEM SEAL WITHOUT STEM ATTACHING SCREWS

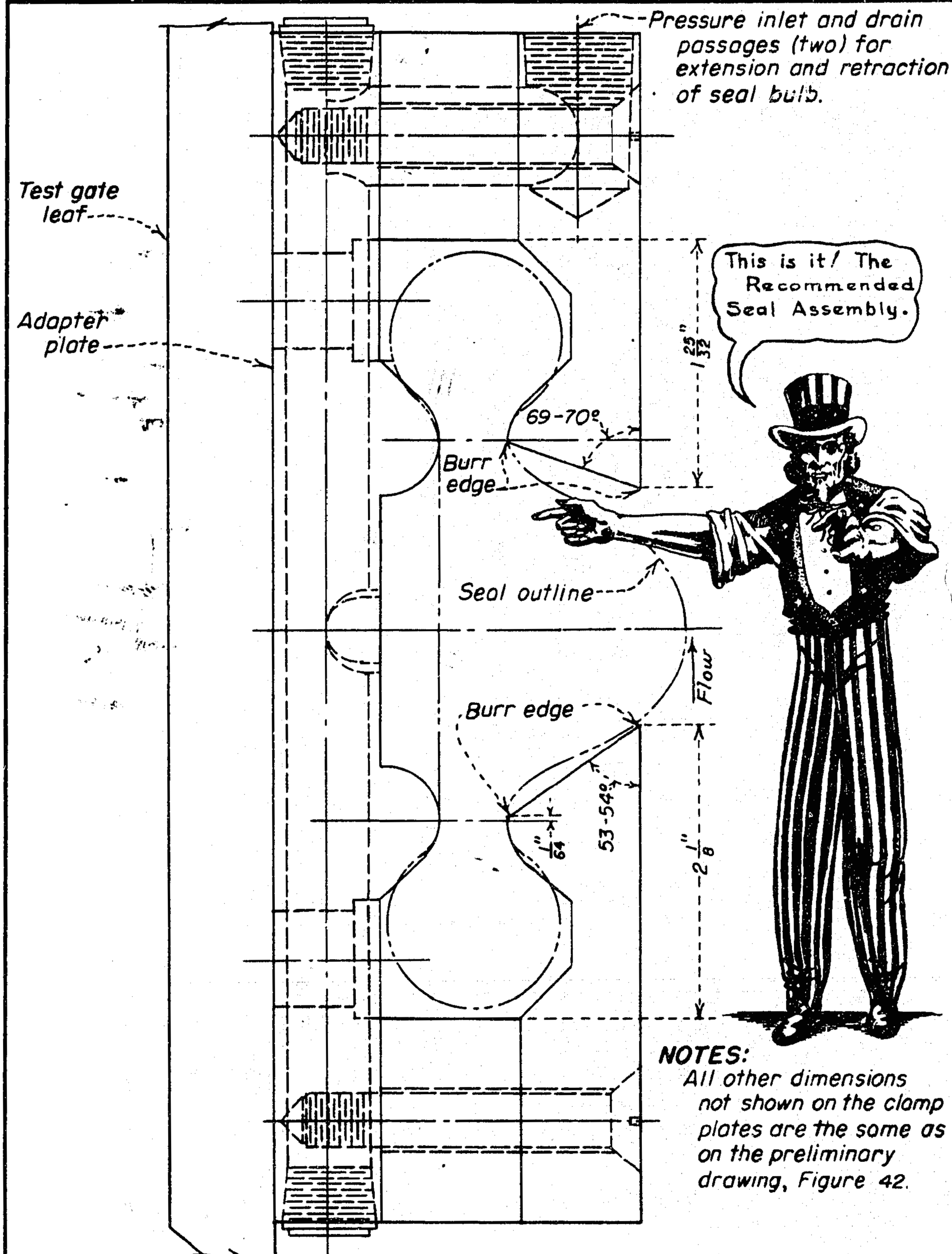
DESIGN NO. 2 - PRELIMINARY

326



HIGH HEAD GATE SEAL STUDIES

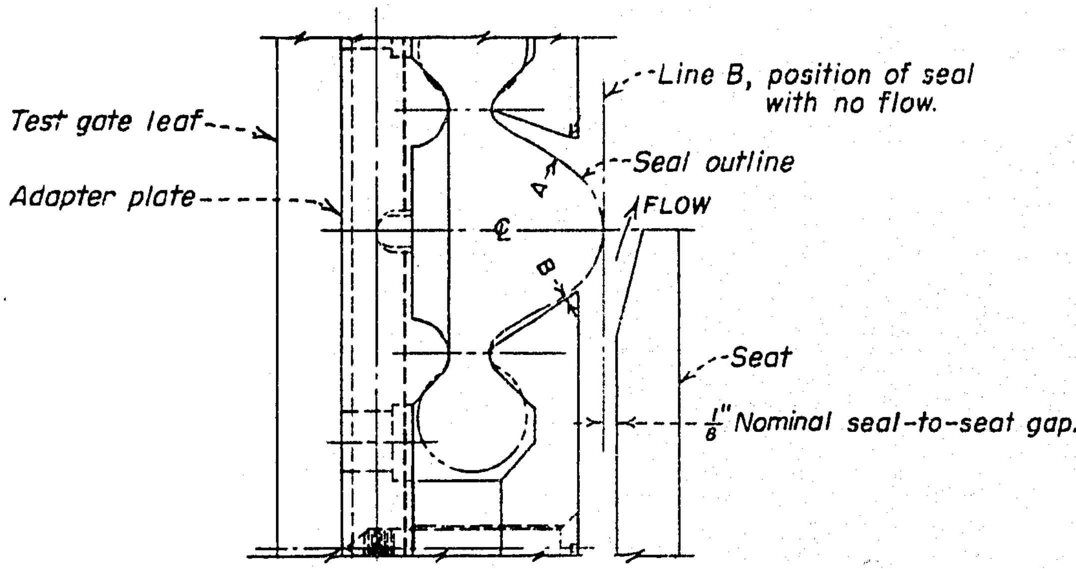
Size comparison of Double Stem Seals with and without Stem Attaching Screws.



HIGH HEAD GATE SEAL STUDIES

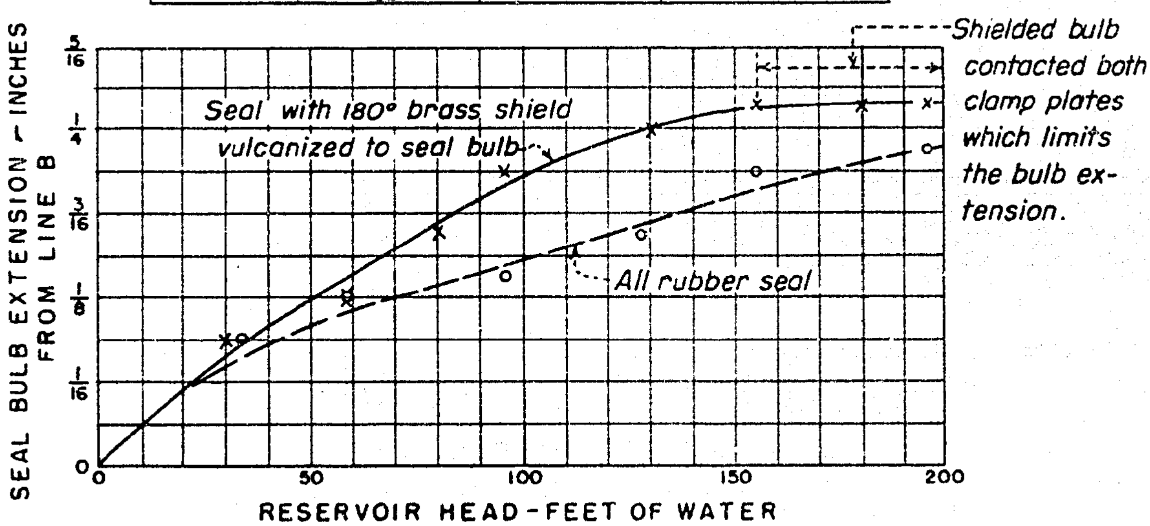
DOUBLE STEM SEAL WITHOUT STEM ATTACHING SCREWS

DESIGN NO. 2 - TEST GATE ASSEMBLY - RECOMMENDED DESIGN



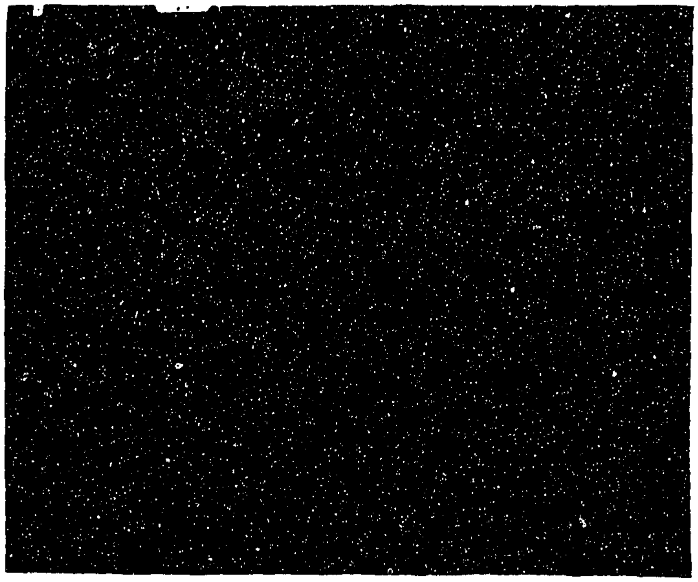
TEST POSITION

CURVE	NO FLOW CLEARANCE		REFERENCE
	A	B	
o——o	$\frac{1}{4}$"	Zero	Figure 43
x——x	$\frac{7}{32}$"	Zero	Figure 42



HIGH HEAD GATE SEAL STUDIES

SEAL BULB EXTENSION VERSUS RESERVOIR HEAD
DOUBLE STEM SEAL WITHOUT STEM ATTACHING SCREWS - DESIGN No. 2



A. Seal with 180 degree brass shield, raised above seat. Bulb was wedged between clamp plates at 160 feet head or more when bulb was extended.

B. Seal without a brass shield and zero seal-to-seat gap. With bulb extended during gate closure, bulb was not pinched at 195 feet head.

HIGH HEAD GATE SEAL STUDIES

Operation of the Double Stem Seal without Stem Attaching Screws
Design No. 2.

APPENDIX

GRAND COULEE FIELD TESTS

OCTOBER 1950

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COULEE DAM, WASHINGTON

November 2, 1950

To: Chief Engineer, Denver, Colorado

From: District Manager

Subject: Experimental Seals for Penstock Coaster Gates--Grand Coulee Dam--Columbia Basin Project.

Reference is made to your teletype DN-CD 845. Three successive stimulated emergency closures were made with the new type experimental seal. No damage was done to the seals during these tests and very low leakage was encountered after each closure. The tests were considered very successful. The following detailed report covers the preparation for and the results of the simulated emergency closure tests using the subject seals. These tests were made using the R-6 coaster gate. A test of a similar nature using the music note type seals is referred to in a letter of November 23, 1949, to Chief Engineer, from District Manager, subject "Closure of R-7 penstock coaster gate under simulated emergency conditions--Grand Coulee Power Plant--Columbia Basin Project."

A. Preparation of Coaster Gate

1. The coaster gate used for this test was one of the three gates furnished under Specifications No. 905. This gate was put in service in June 1941 and was removed from service during October 1949 to permit installation of new seals (see letter December 16, 1949 to Chief Engineer, from District Manager, subject "Report on condition of main unit L-3 penstock coaster gate--Grand Coulee Power Plant--Columbia Basin Project"). It was subsequently installed in the R-6 position on April 24, 1950. The controls were tested and operation of the gate was deemed satisfactory.

2. Removal of the coaster gate was accomplished on August 25, 1950. The seal bases were removed and then taken to the machine shop for alteration in accordance with Drawing No. 222-D-15067. The roller chains were noted to be in an inoperable condition at this time due to corrosion. (See photograph No. 3-22706.) The chains were removed from the gate,

soaked in solvent, and worked by mechanical means until each roller and link was free to move. The links were treated with Texaco Type L rust preventive compound before the chains were reinstalled on the gate. After installing the chains on the gate, it was just possible to rotate them using an air tugger which exerted a 1-ton pull. After completion of the tests, the chains could not be rotated using the same pull. The probable reason for the high resistance to rotation is that this coaster gate was equipped with roller chains having unbalanced or double links, whereas subsequent coaster gate chains incorporated the balanced or triple type links.

B. Installation of the experimental seal.

1. Installation of the experimental seal (Drawing No. 222-D-14970) was made in accordance with the March 15, 1950 revision of Drawing No. 222-D-15067. The miter joints in the corners of the seals were vulcanized in place on the gate. Photographs Nos. 3-22820, 3-22821 and 3-22822 were taken during the installation of the seal.

2. After the installation of the seal was completed, clearance readings were taken on the seals at the points indicated on Figure 1. Readings on the vertical seals were taken with a gage inserted between every other pair of rollers using the roller track for a reference plane as shown in photograph No. 3-22819. A wire was strung parallel to the top and bottom seals and the clearance readings taken between the seal and the brass seal seat on the dam is 1/16 inch (+0, -1/16") as shown on Drawing No. 222-D-9732, but this was not attained on all parts of the seals. See figures 3 and 4 for the readings obtained.

3. The dimensions of the rubber seal furnished were checked for conformance to those shown on Drawing No. 222-D-14970. Every dimension was found to be as large as the tolerances permitted. This in part accounts for not attaining the normal seal clearance.

C. Initial gate sealing to remove penstock bulkhead.

On September 14, 1950, the coaster gate was operated and the penstock bulkhead was drained. The first attempt to drain the bulkhead (by opening the 6" drain valve) was considered a failure after 35 minutes. The gate was completely raised and again lowered with the same results on the second attempt. On the third trial, the gate was raised about one foot, then with the 6-inch drain valve open, the gate was allowed to settle by opening the by-pass valve on the coaster gate control piping. The results of this closure were very good (see photographs Nos. 3-22847 and 3-22848). Leakage past the seals was estimated to be 25 gallons per minute.

D. Action of the seal.

With the penstock drained, the movement of the experimental seal appeared to be limited to the slight movement towards the brass seat necessary to prevent leakage. Excessive deformation of the seal was not apparent. (See photograph No. 3-22850.)

E. Effectiveness of the seal after the generator dryout run.

An inspection was made of the coaster gate leakage after completion of the dryout run. The seal was obtained by closing the wicket gates, lowering the coaster gate, and opening the penstock drain valve. Leakage past the seals was estimated to be 200 gallons per minute at this time with several leaks apparent. (See figure 6.)

F. Method used in simulating emergency shutdown.

The conditions under which an emergency shutdown was simulated were fixed wicket gate opening and constant unit speed. These conditions were maintained by beginning with the unit on the line with a load of 108 megawatts. The coaster gate was then tripped and the unit gradually dropped its load in order to hold synchronous speed. The conclusion of this step was motoring the unit before opening the generator circuit breaker so that the wicket gates would not close when the unit separated from the transmission system.

G. Effectiveness of seal after each of the three emergency shutdowns.

1. The first emergency shutdown was made on October 9, 1950. Inspection of the coaster gate was made shortly after the shutdown and revealed several small leaks past the seals. (See figure 6.) Leakage was estimated to be 150 gallons per minute.

2. The second emergency shutdown was also made on October 9, 1950. Inspection of the gate this time revealed a number of quite small leaks. (See Figure 6.) Leakage was estimated to be 75 gallons per minute.

3. The third emergency closure was made on October 10, 1950. The leakage this time was limited to one large leak near the top of the left vertical seal and a small amount of water coming in under the inner clamp bar on the opposite side. (See Figure 6.) Leakage was estimated to be 100 gallons per minute.

H. Operational data during the shutdowns.

Figure 5 shows all of the operational data pertinent to the emergency closures. These figures are representative of all three shutdowns. It was noted that the pressure in the scroll case dropped very slowly after the unit was separated from the transmission system. This is due to the fact that the turbine acts as a centrifugal pump and holds pressure in the penstock proportional to its speed.

I. Condition of the seal after testing.

1. The coaster gate was removed from the slot on October 11, 1950 to permit inspection of the seals. A visual inspection of the seals revealed no apparent damage. A slight tendency for the seals to creep towards the middle of the gate was noted. (See photographs Nos. 3-22984, -985, -986, and -987.) The last photograph shows a pulled down condition of the seal at the top right corner which was due to a material shortage on the vertical seal on installation. This existing condition appeared to be unchanged by the closure tests.

2. Another set of seal clearance readings, similar to those taken before installation of the gate, were taken. Using the gage inserted between a pair of rollers and using the roller track as a reference plane, readings (See Figures 3 and 4) to the vertical seals were taken but not at the same locations as previously, because the roller chains could not be rotated as was mentioned in paragraph A-2.

3. The average seal clearances both before and after the closure tests are shown below, also shown is the average change in the seal clearances during the tests. The normal recommended clearance between the seal and the seal seat on the dam is 1/16 inch (+0, -1/16-inch).

	Initial Clearance	Final Clearance	Change in Clearance
Top seal	.076 inch	.081 inch	+.006 inch
Bottom seal	.042 inch	.031 inch	-.011 inch
Right vertical seal	.092 inch	.020 inch	-.072 inch
Left vertical seal	.084 inch	.016 inch	-.068 inch

(The above average readings are to be considered accurate within ± 1/64 inch.)

J. Roller chains.

The roller chains appeared to have functioned satisfactorily, however, this might not have been true if the chains had not been worked over prior to the test. It is felt that this vital portion of the gate should be made of corrosion resistant steel.

The rubber used in the subject seal was softer than previous seals but of very good quality, it vulcanized very well and no joint, field or factory, showed any stress or failure after the tests. The rubber bulb of the seal appeared to be sufficiently confined by the clamp bars so that no maladjustments resulted from the emergency closures. The possibility of replacing the coaster gate top and bottom seals only with the type of seal used on these emergency closure tests has been mentioned in previous conversations between your office and the project personnel. Your further comments on this possibility are invited.

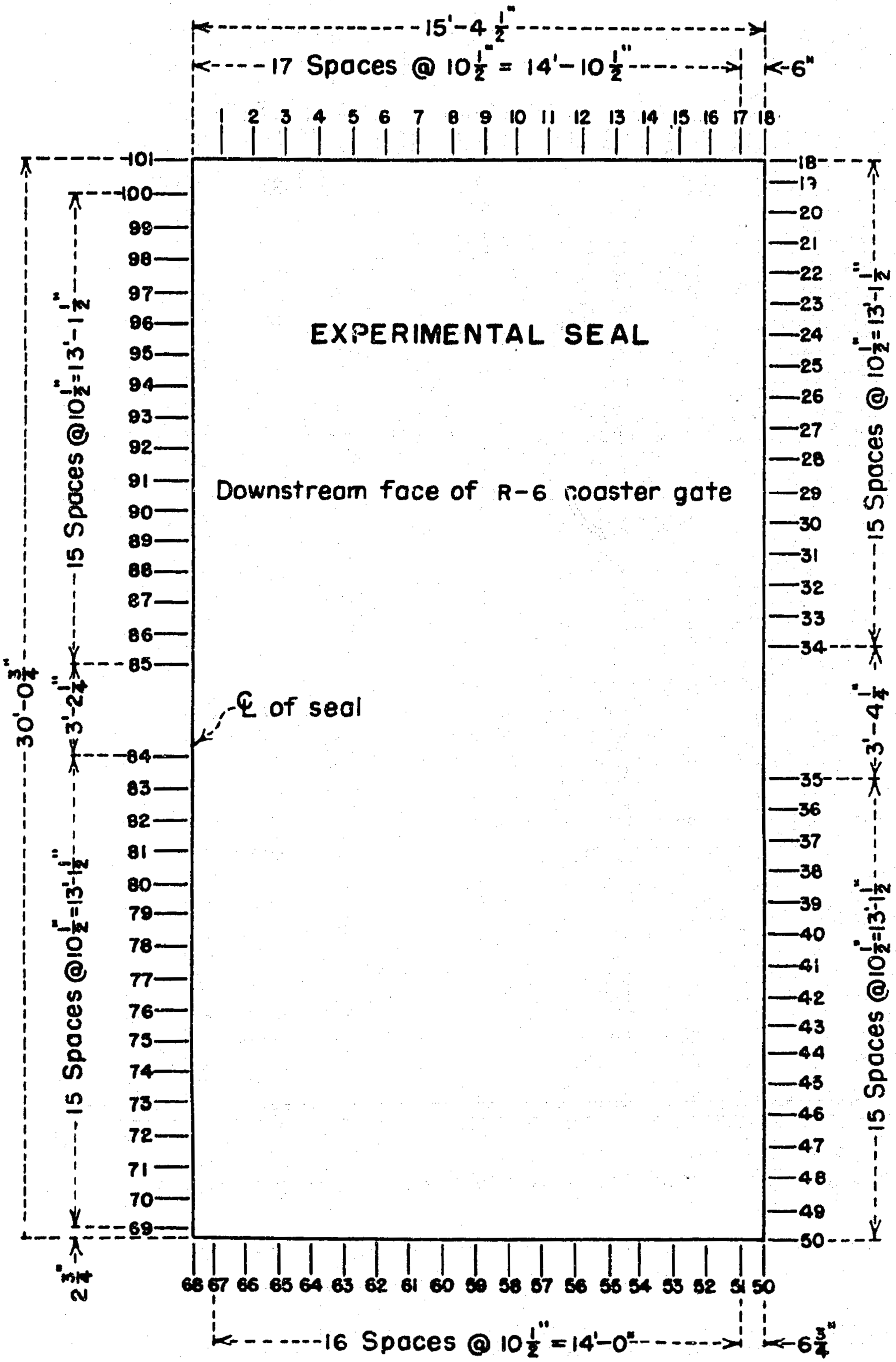
For the District Manager

(Sgd.) F. J. Sharkey
Acting Supervising Engineer

Enclosure: 12 photographs
6 data sheets

Copy to: Regional Director, Boise, Idaho
(with data sheets only)

FIGURE 1

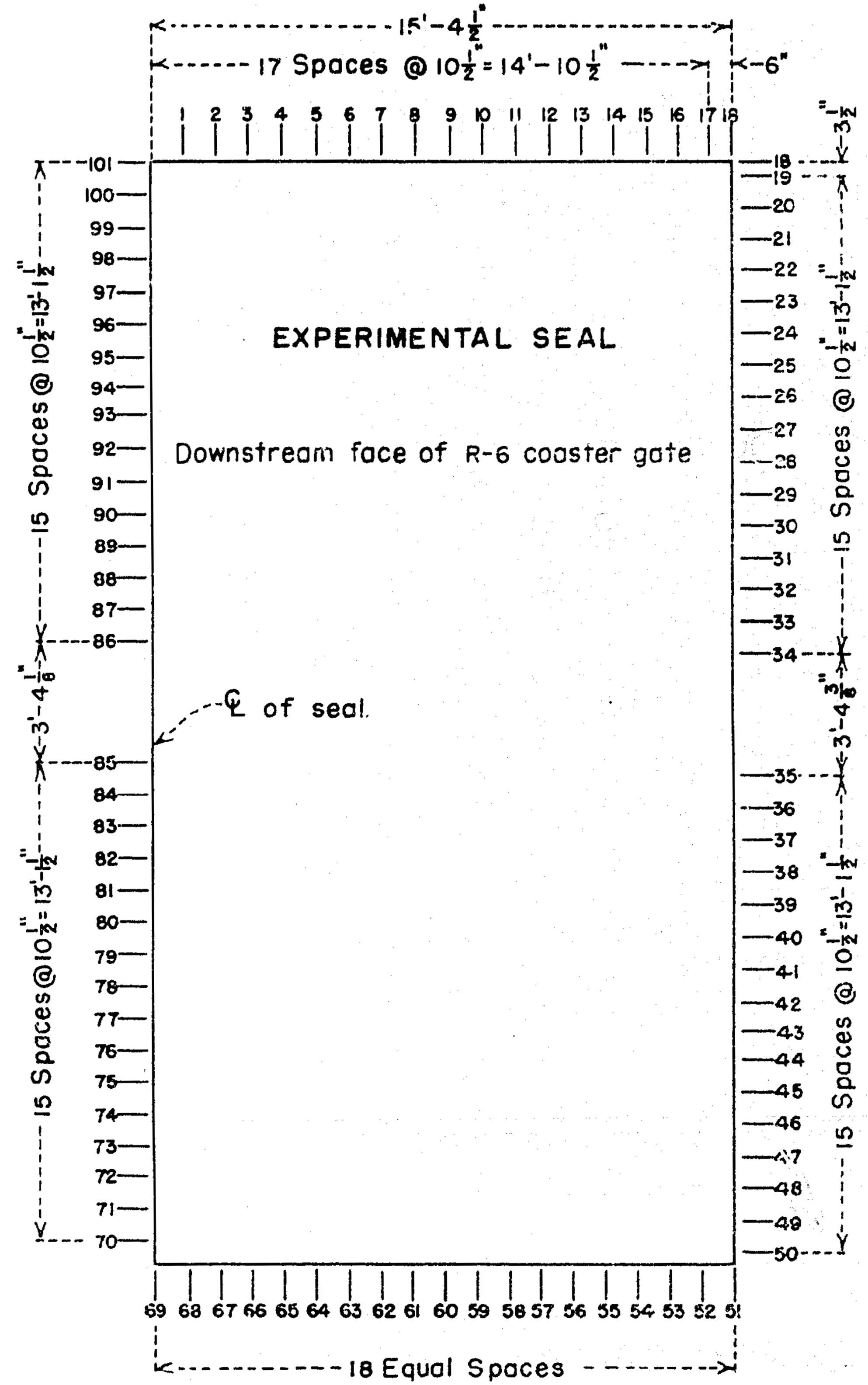


POSITIONS AT WHICH SEAL CLEARANCES WERE MEASURED

SEPTEMBER 14, 1950

320

FIGURE 2



POSITIONS AT WHICH SEAL CLEARANCES WERE MEASURED

OCTOBER 11, 1950

320

Figure 3

Position	Clearance	
	Sept. 14	Oct. 11
1	0.062	0.078
2	0.062	0.062
3	0.062	0.062
4	0.062	0.062
5	0.062	0.078
6	0.062	0.078
7	0.062	0.156
8	0.062	0.093
9	0.062	0.078
10	0.062	0.078
11	0.062	0.078
12	0.094	0.093
13	0.094	0.062
14	0.094	0.078
15	0.094	0.078
16	0.094	0.078
17	0.062	0.093
18	0.156	0.125
19	0.074	0.031
20	0.089	0.031
21	0.124	0.000
22	0.102	0.031
23	0.109	0.000
24	0.119	0.000
25	0.104	0.000
26	0.099	0.000
27	0.099	0.031
28	0.092	0.031
29	0.128	0.000
30	0.094	0.000
31	0.092	0.000
32	0.094	0.015
33	0.092	0.000
34	0.084	0.000

Position	Clearance	
	Sept. 14	Oct. 11
35	0.079	0.000
36	0.079	0.031
37	0.074	0.015
38	0.079	0.015
39	0.074	0.031
40	0.084	0.031
41	0.064	0.031
42	0.064	0.000
43	0.061	0.031
44	0.066	0.046
45	0.089	0.031
46	0.089	0.015
47	0.089	0.000
48	0.089	0.031
49	0.089	0.031
50	0.104	0.046
51	0.000	0.000
52	0.031	0.000
53	0.000	0.031
54	0.062	0.031
55	0.062	0.031
56	0.000	0.046
57	0.093	0.062
58	0.000	0.046
59	0.000	0.031
60	0.093	0.031
61	0.093	0.031
62	0.000	0.046
63	0.094	0.046
64	0.094	0.046
65	0.000	0.046
66	0.000	0.031
67	0.000	0.015
68	-0.062	0.015

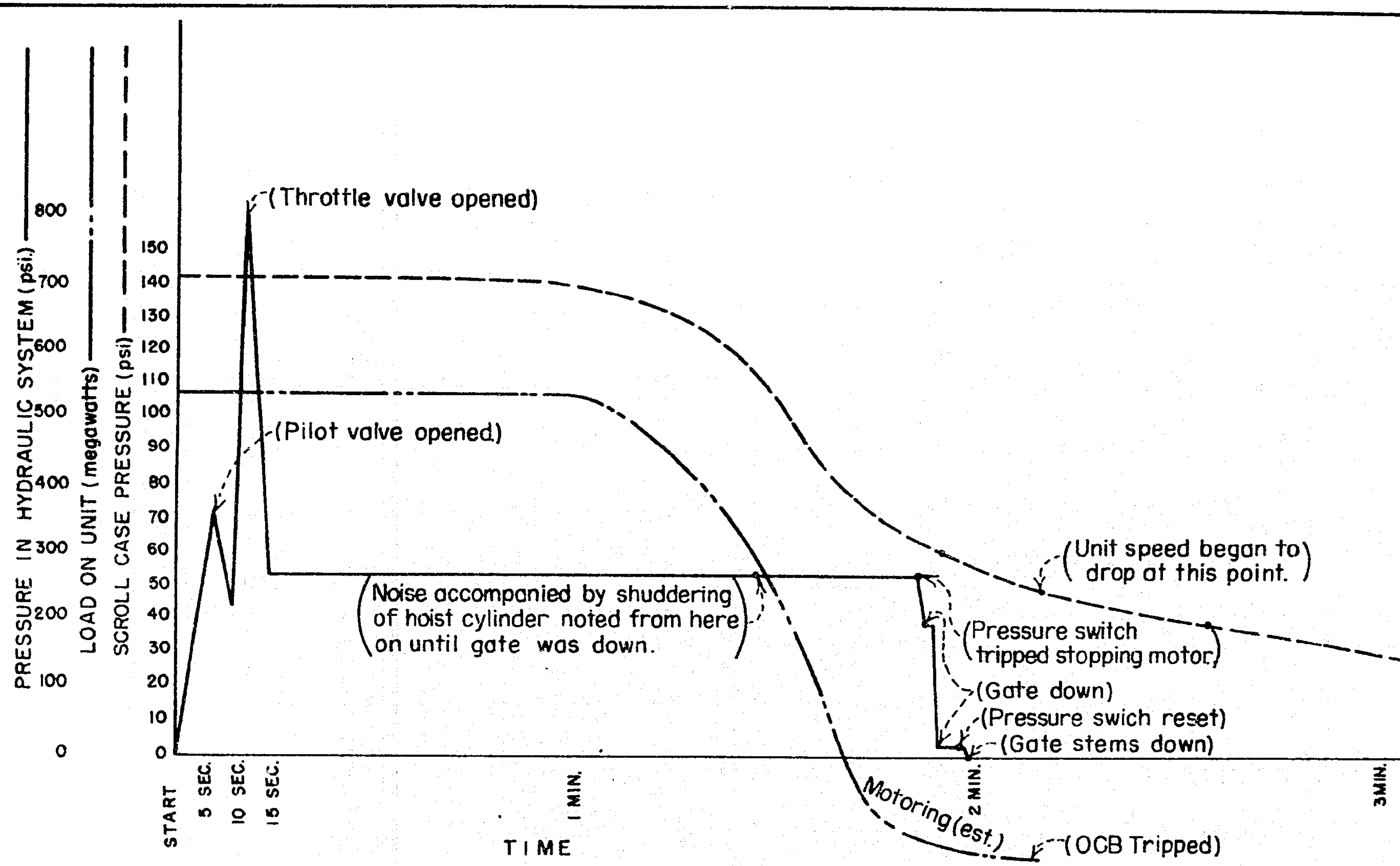
Figure 4

Position	Clearance Sept. 14	Clearance Oct. 11
69	0.104	0.000
70	0.118	-0.015
71	0.112	0.000
72	0.104	0.000
73	0.119	0.015
74	0.102	0.015
75	0.084	0.000
76	0.086	0.031
77	0.069	0.031
78	0.069	0.046
79	0.089	0.046
80	0.089	0.031
81	0.089	0.015
82	0.089	0.000
83	0.079	0.015
84	0.063	0.031
85	0.074	0.000
86	0.079	0.031
87	0.074	0.000
88	0.062	0.031
89	0.059	0.031
90	0.099	0.031
91	0.089	0.000
92	0.092	0.000
93	0.064	0.000
94	0.092	0.000
95	0.102	0.031
96	0.092	0.031
97	0.102	0.000
98	0.092	0.015
99	0.062	0.000
100	0.120	0.031
101	0.062	0.031

Clearance is distance from seal to seal seat with gate in postion as shown on Drawing No. 222-D-9732; recommended minimum clearance is .062 inch

- sign indicates interference.

Accuracy of readings is ± 1/64 inch.

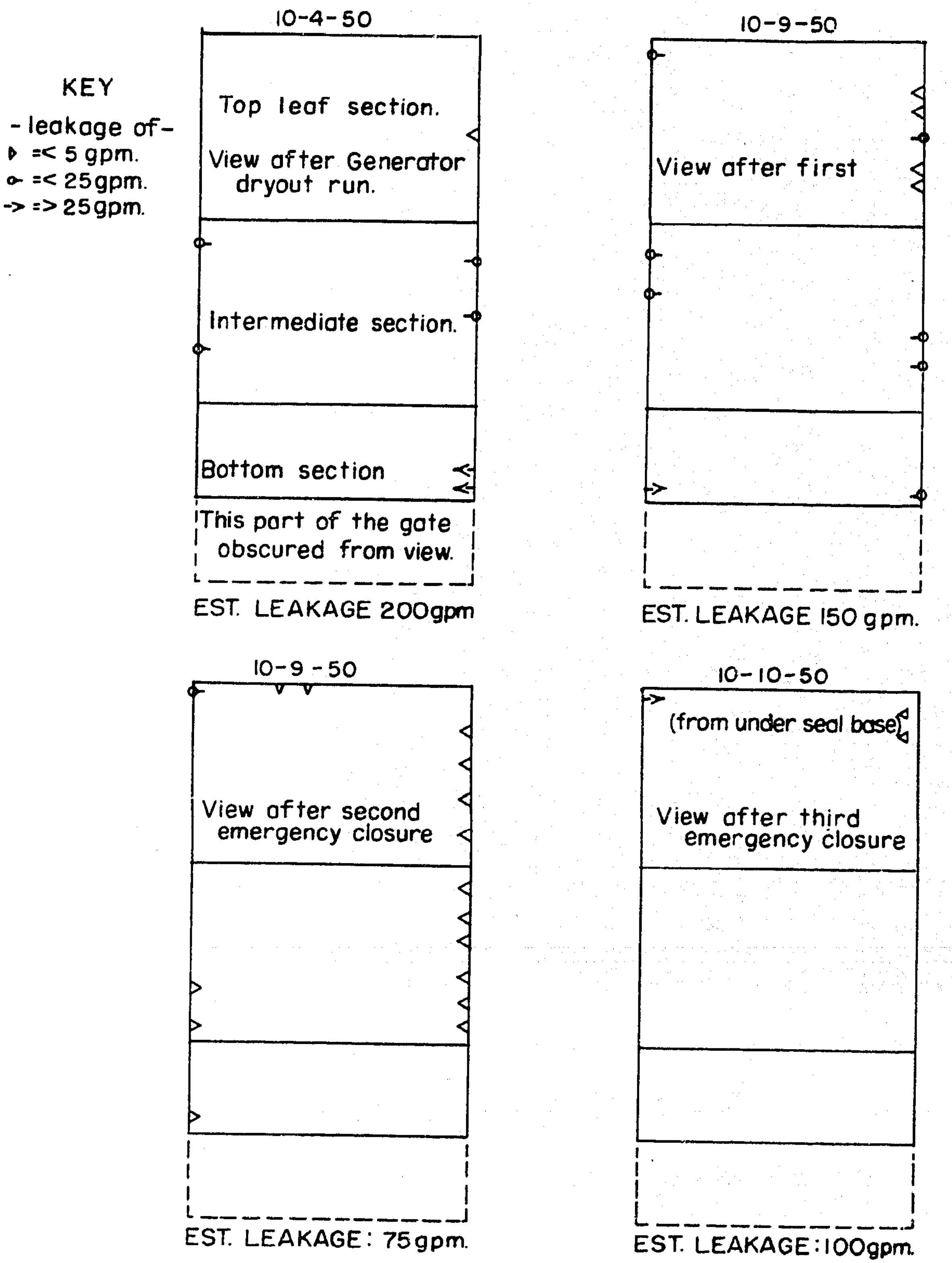


COASTER GATE CLOSURE DATA

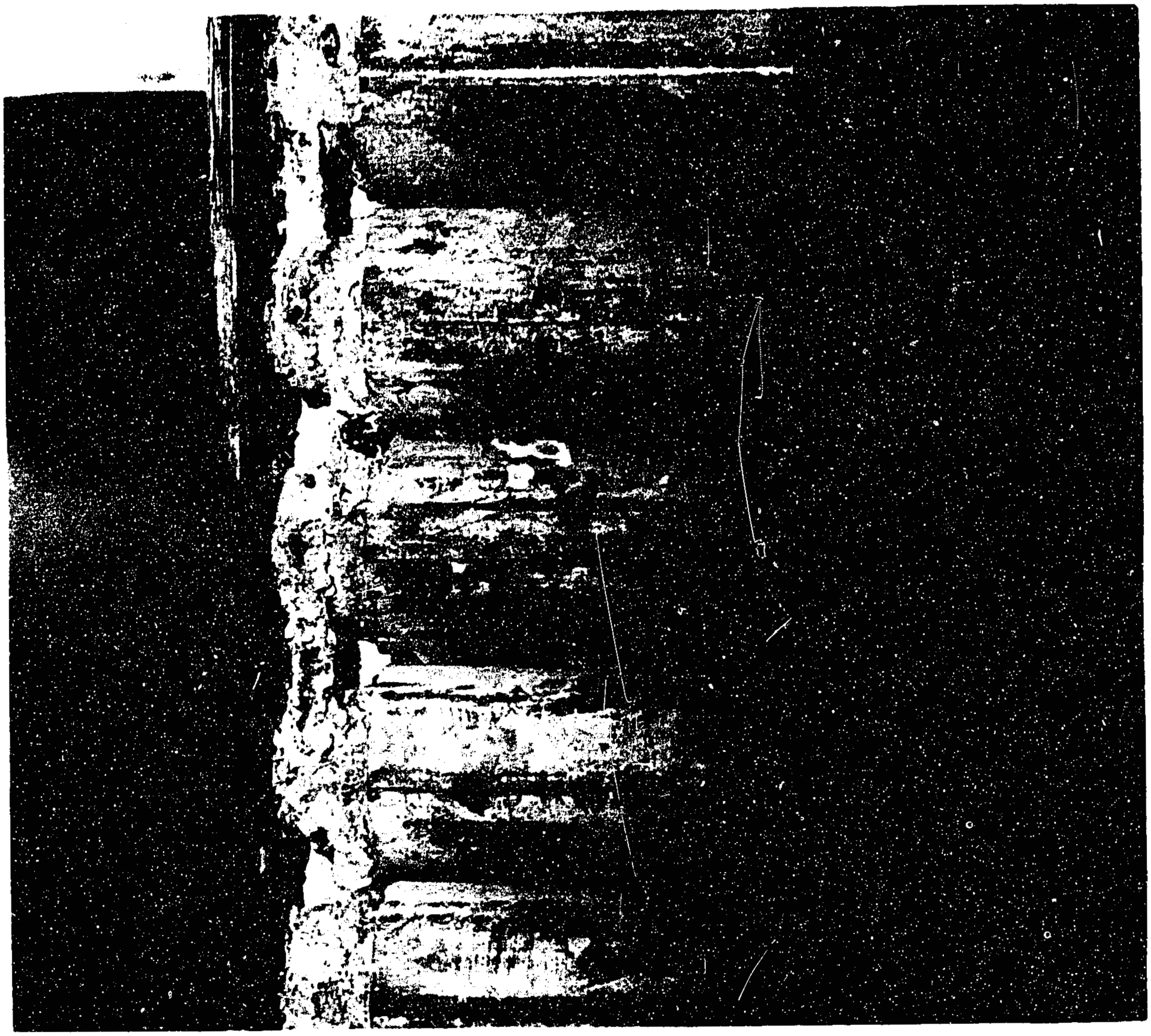
320

FIGURE 5

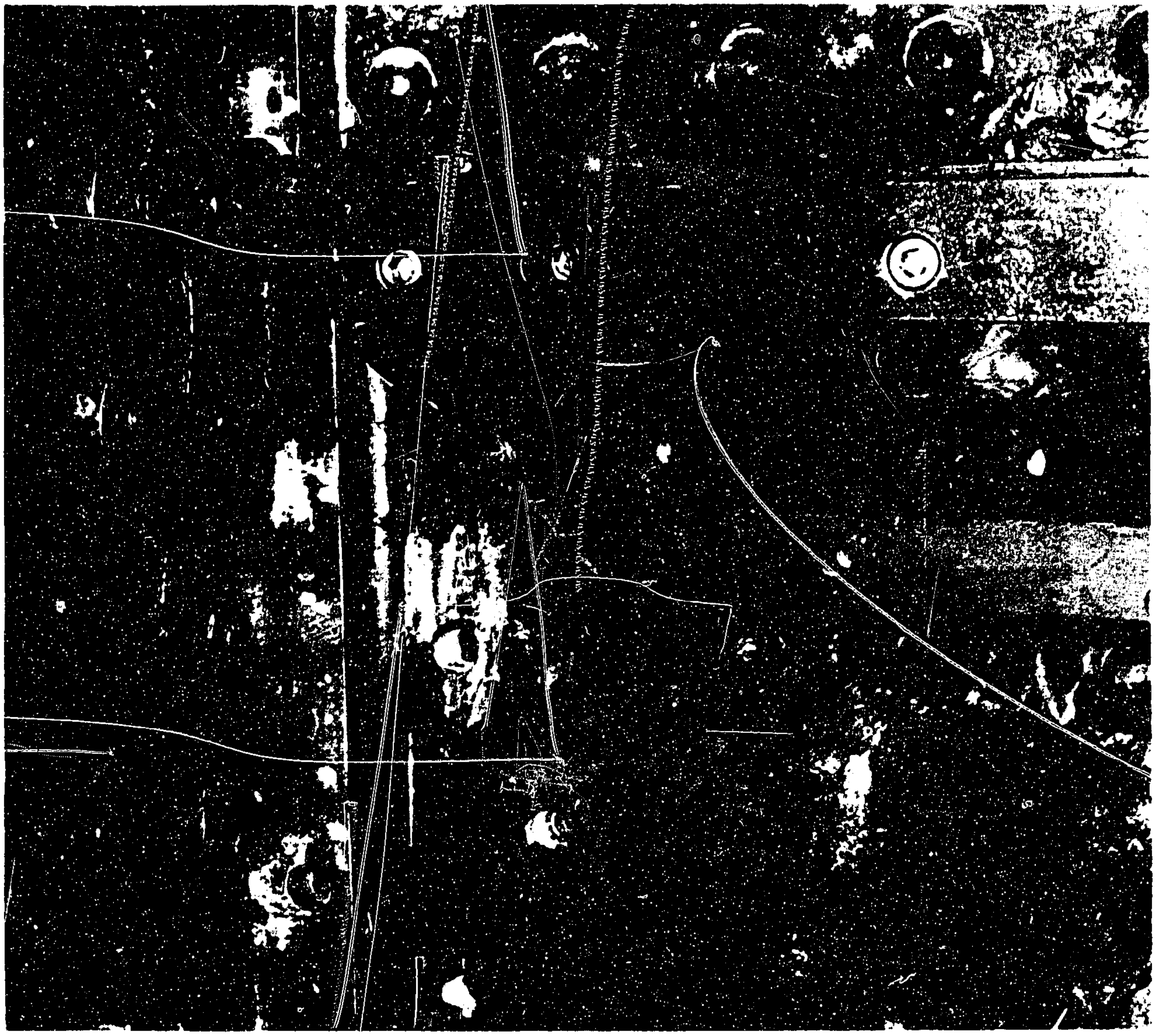
FIGURE 6



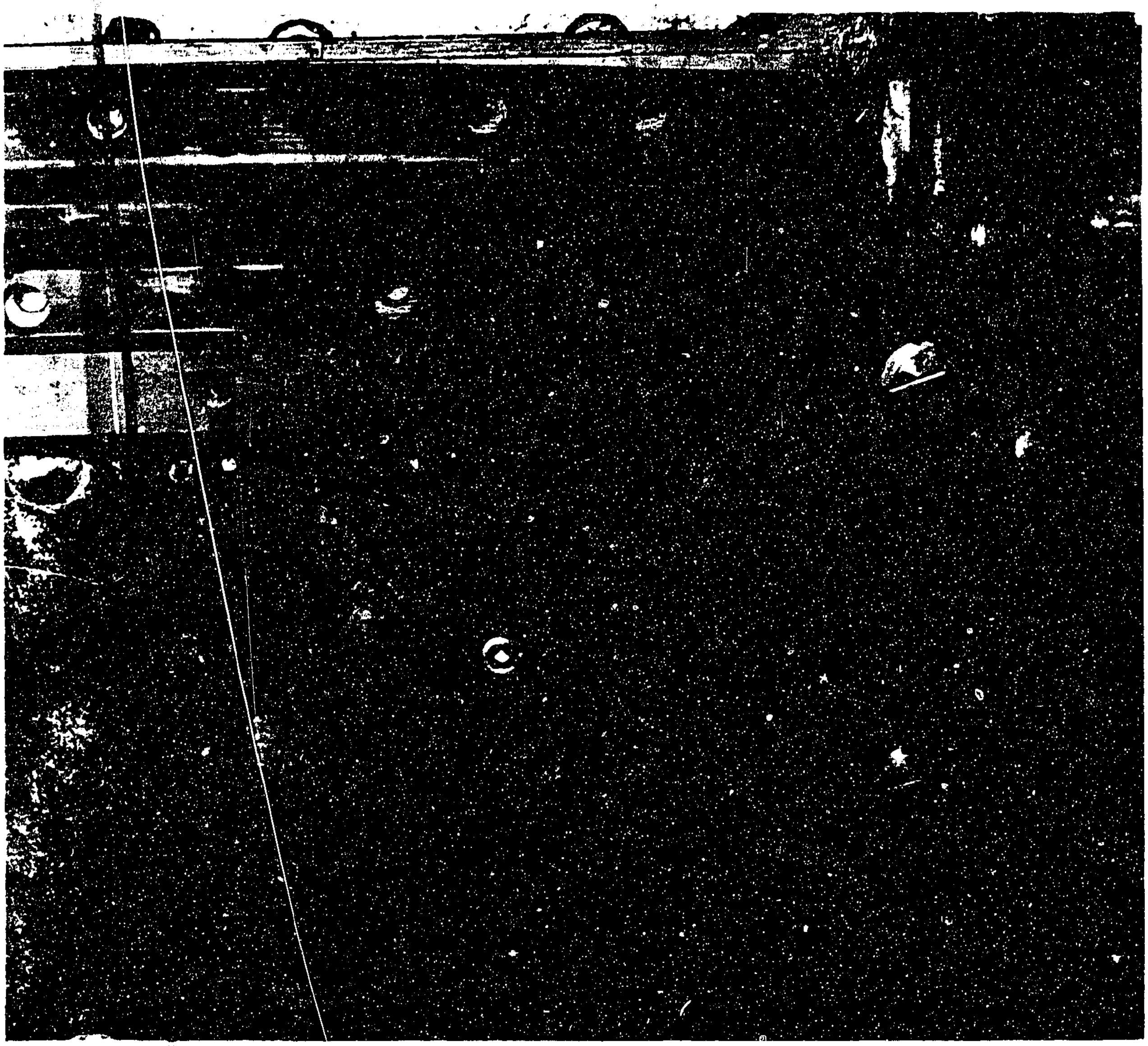
R-6 COASTER GATE LEAKAGE



R-6 coaster gate (formerly L-3) lower right roller chain. Photo shows corrosion of the steel chain links. This gate was in service from June, 1941 until November, 1949, and from April, 1950 until August, 1950. The chains are in an inoperable condition, and it may be noted that their sliding action in operation has slightly flattened the contact surface. After removing the rust from the links, many pits were found to be in excess of 1/16 " in depth. August 30, 1950.



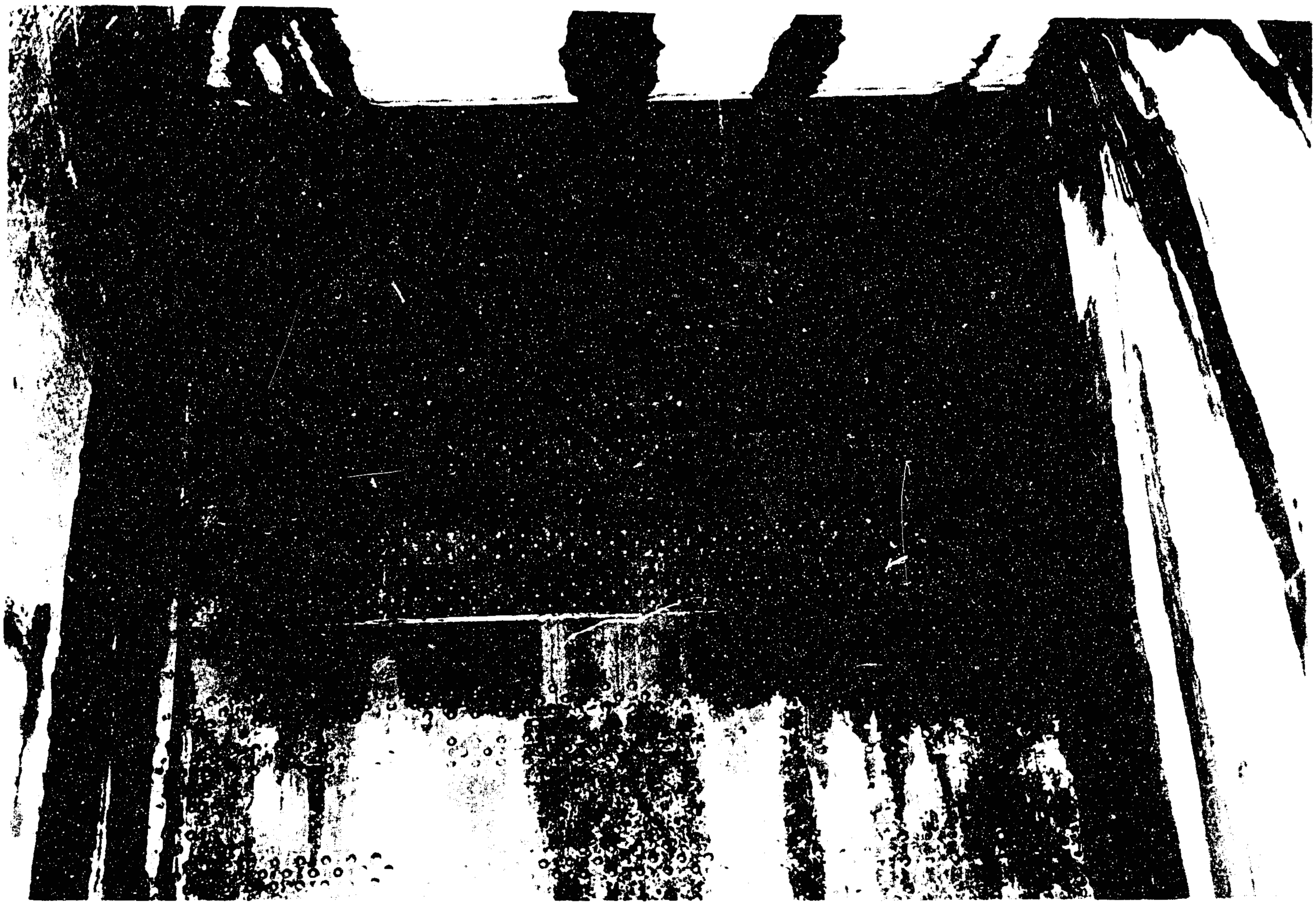
The R-6 coaster gate which was formerly installed in L-3 and furnished under Specifications No. 905, showing installation of the experimental seal (Reference Drawing No. 222-D-15067). This close-up shows the top left corner of the seal during installation of the clamp bars. September 13, 1950.



The R-6 coaster gate which was formerly installed in L-3 and was furnished under Specifications No. 905, showing installation of the experimental seal (Reference Drawing No. 222-D-15067). This close-up shows the top right corner after the completion of field vulcanizing. September 13, 1950.

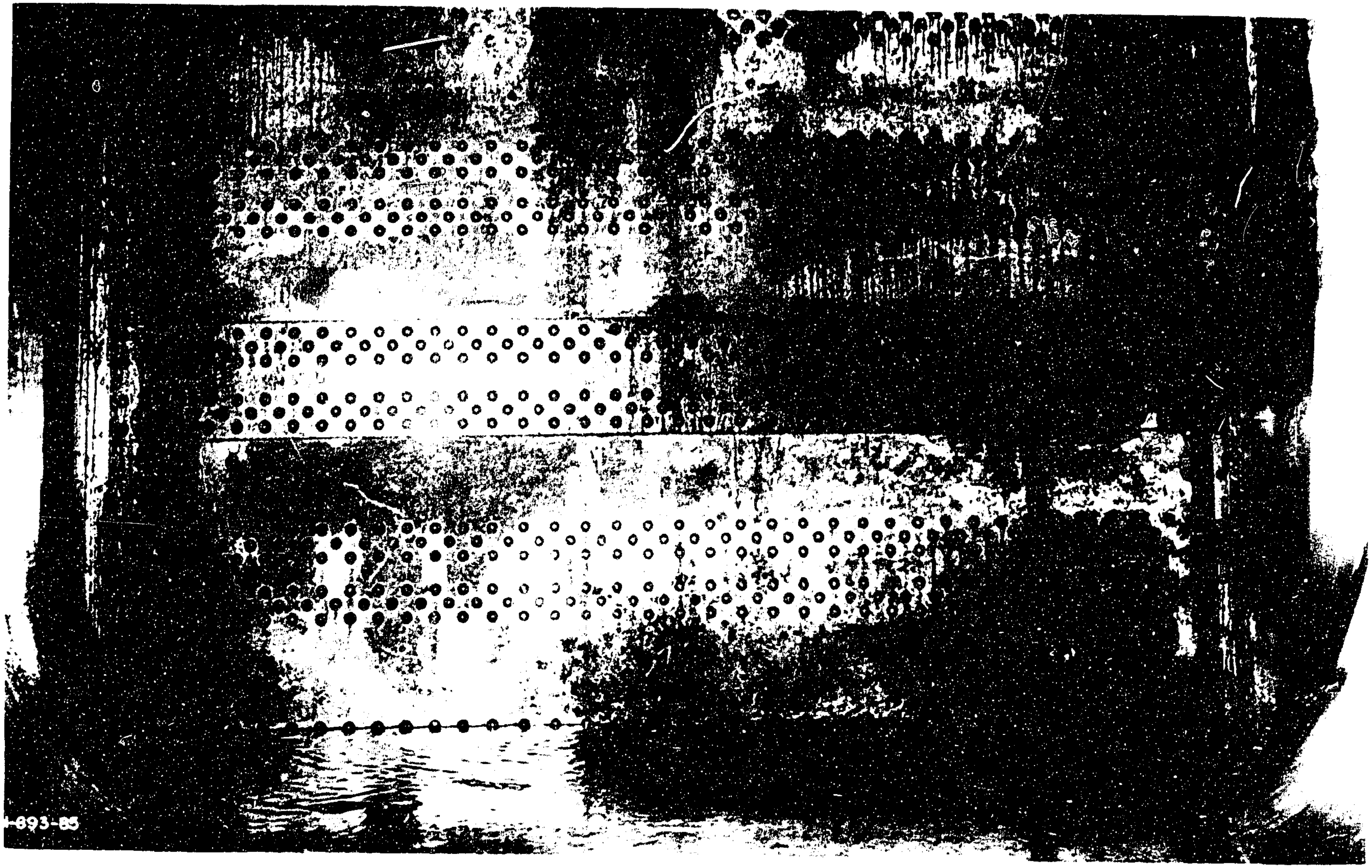
The R-6 coaster gate which was formerly installed in L-3 and was furnished under Specifications No. 905, showing installation of the experimental seal (Reference Drawing No. 222-D-15067). This view of the seal was taken of the upper right hand side of the gate. September 13, 1950.

The R-6 coaster gate which was formerly installed in L-3 and was furnished under Specs. No. 905, showing installation of the experimental seal (Reference Drawing No. 222-D-15067). Use of the seal clearance gauge is shown. The gauge was inserted between the rollers and firmly seated against the roller track. A clearance of 1/16" between the seal and the gauge is the normal setting. September 13, 1950.



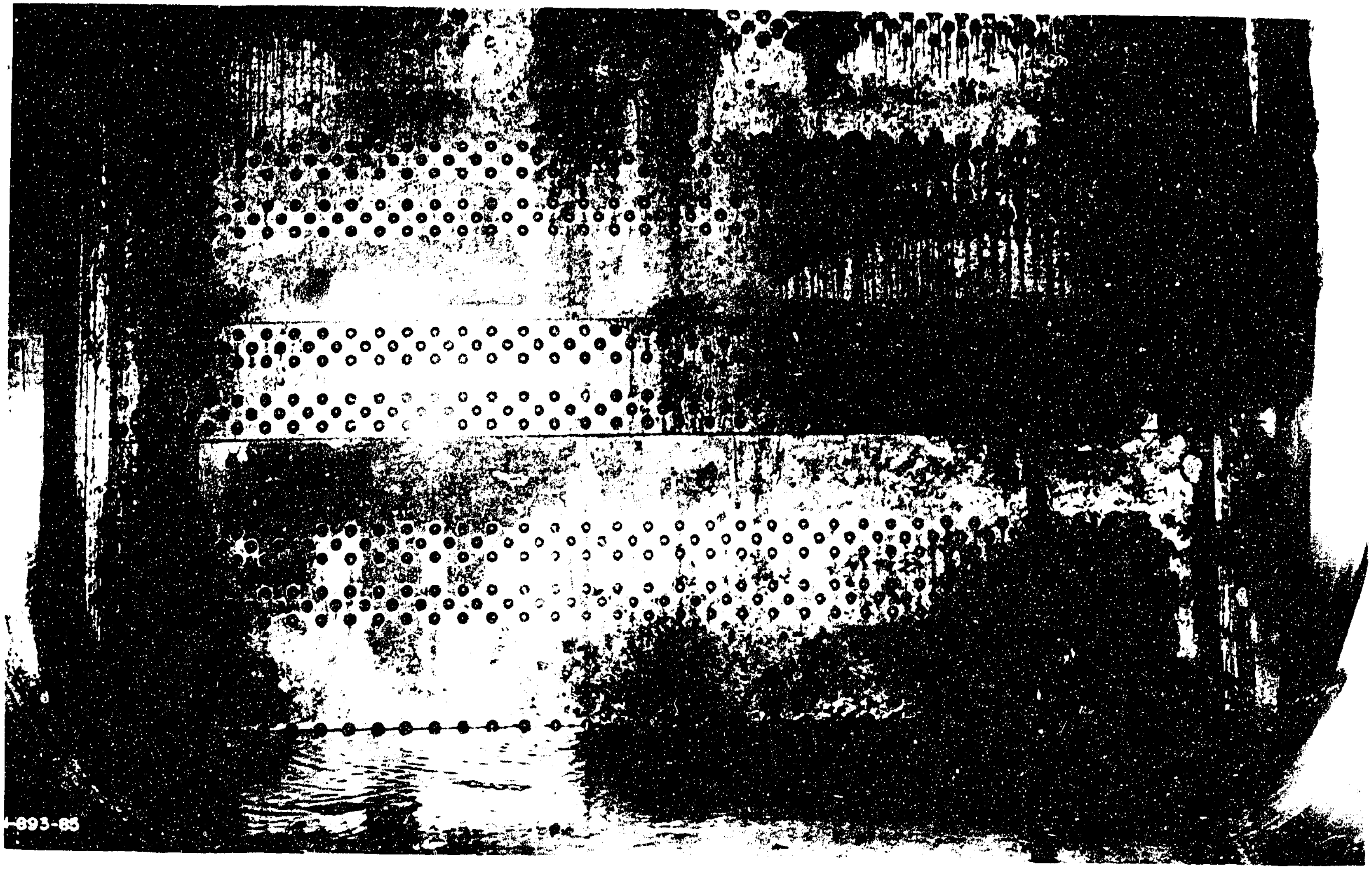
The coaster gate, formerly installed in Unit L-3, is shown installed in the R-6 penstock. The gate is equipped with the experimental seal (Reference Drawing No. 222-D-15067). Total leakage past the gate was estimated to be 25 gallons per minute. The top half of the gate is shown in the photo. September 20, 1950.

Report Hyd. 311 Photo No. 3-22847



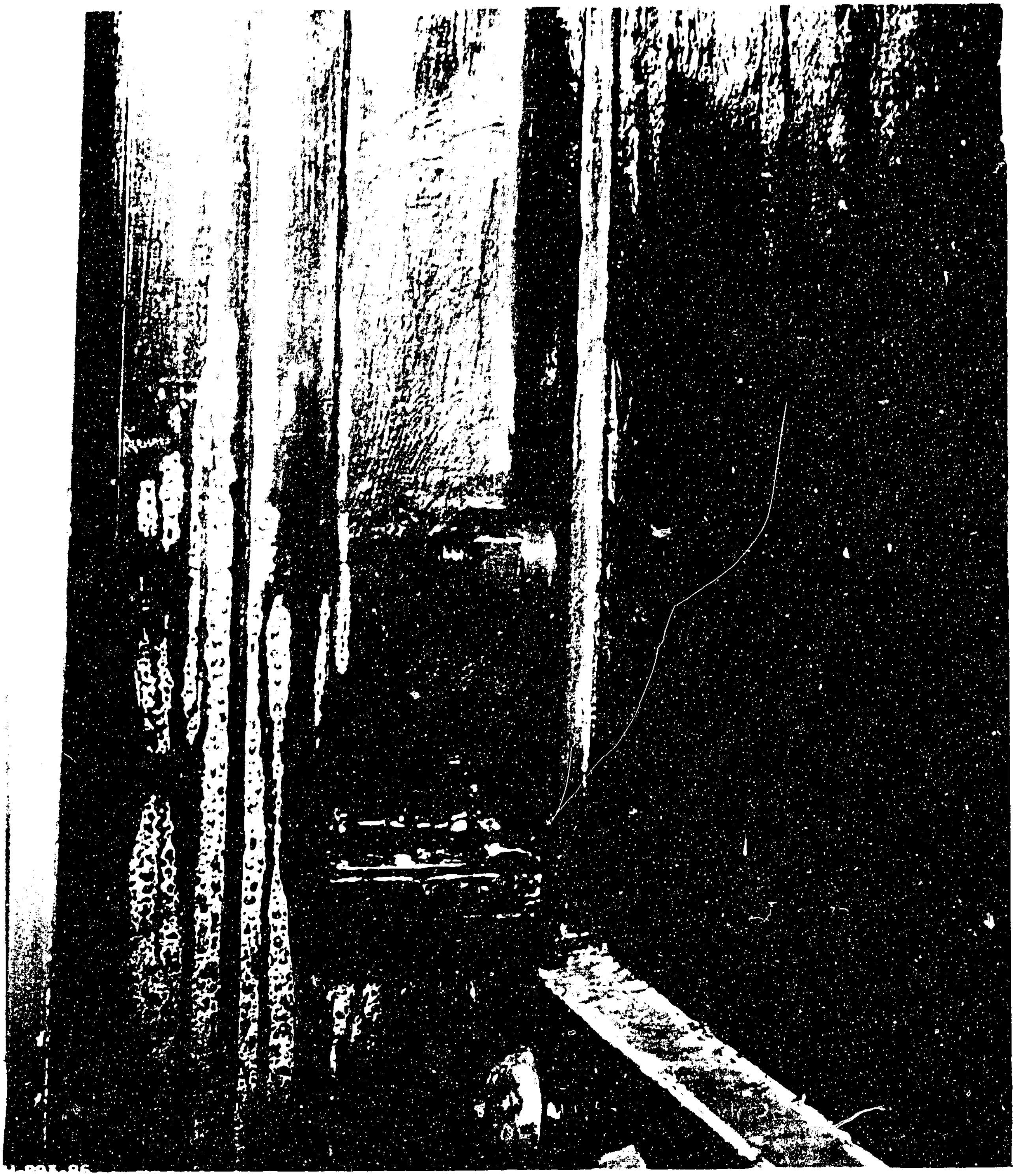
The coaster gate, formerly installed in Unit L-3, is shown installed in the R-6 penstock. The gate is equipped with the experimental seal (Reference Drawing No. 222-D-15067). Total leakage past the gate was estimated to be 25 gallons per minute. The bottom half of the gate is shown in the photo. September 20, 1950.

Report Hyd. 311 Photo No. 3-22848

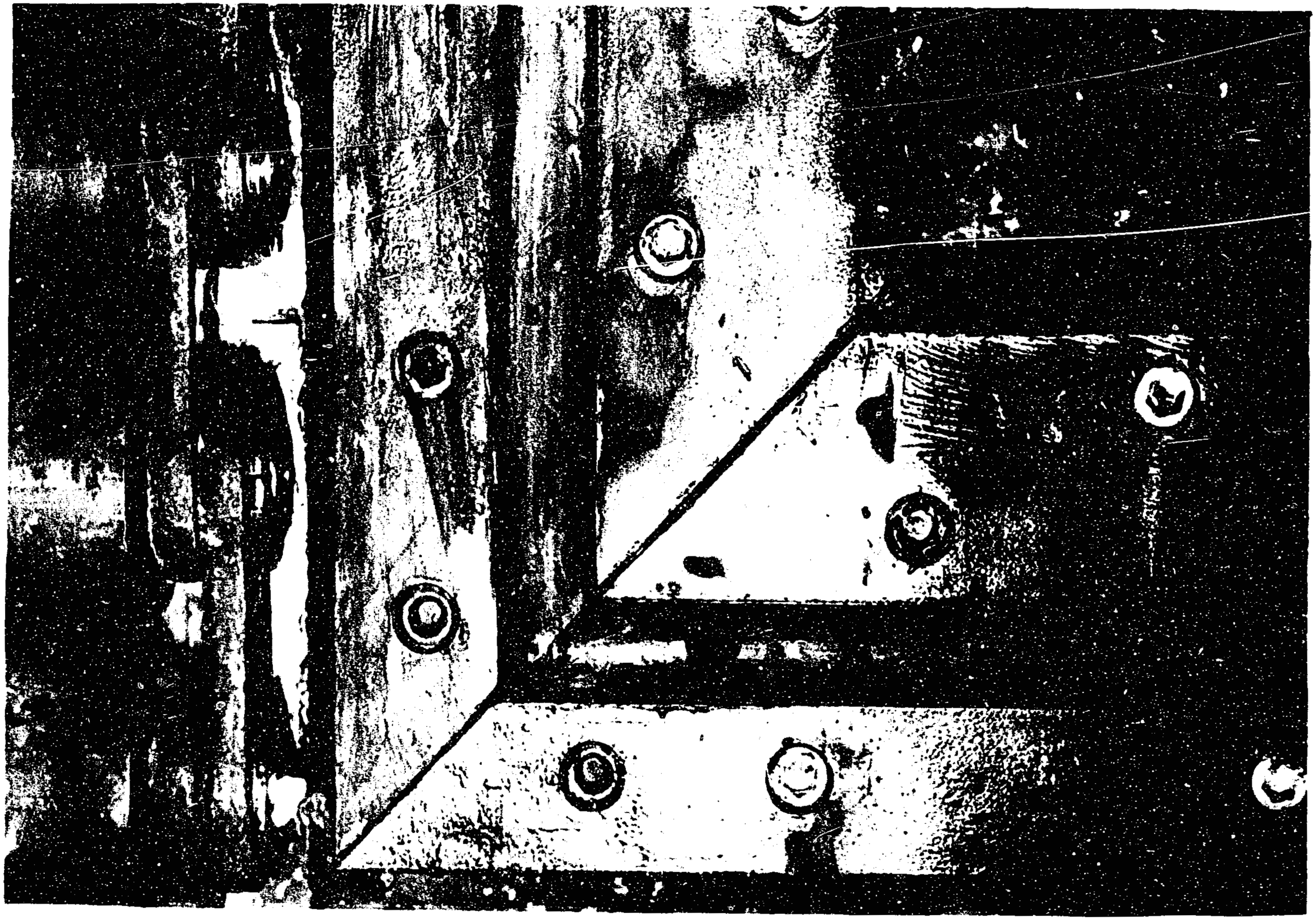


Report Hyd. 311 Photo No. 3-22848

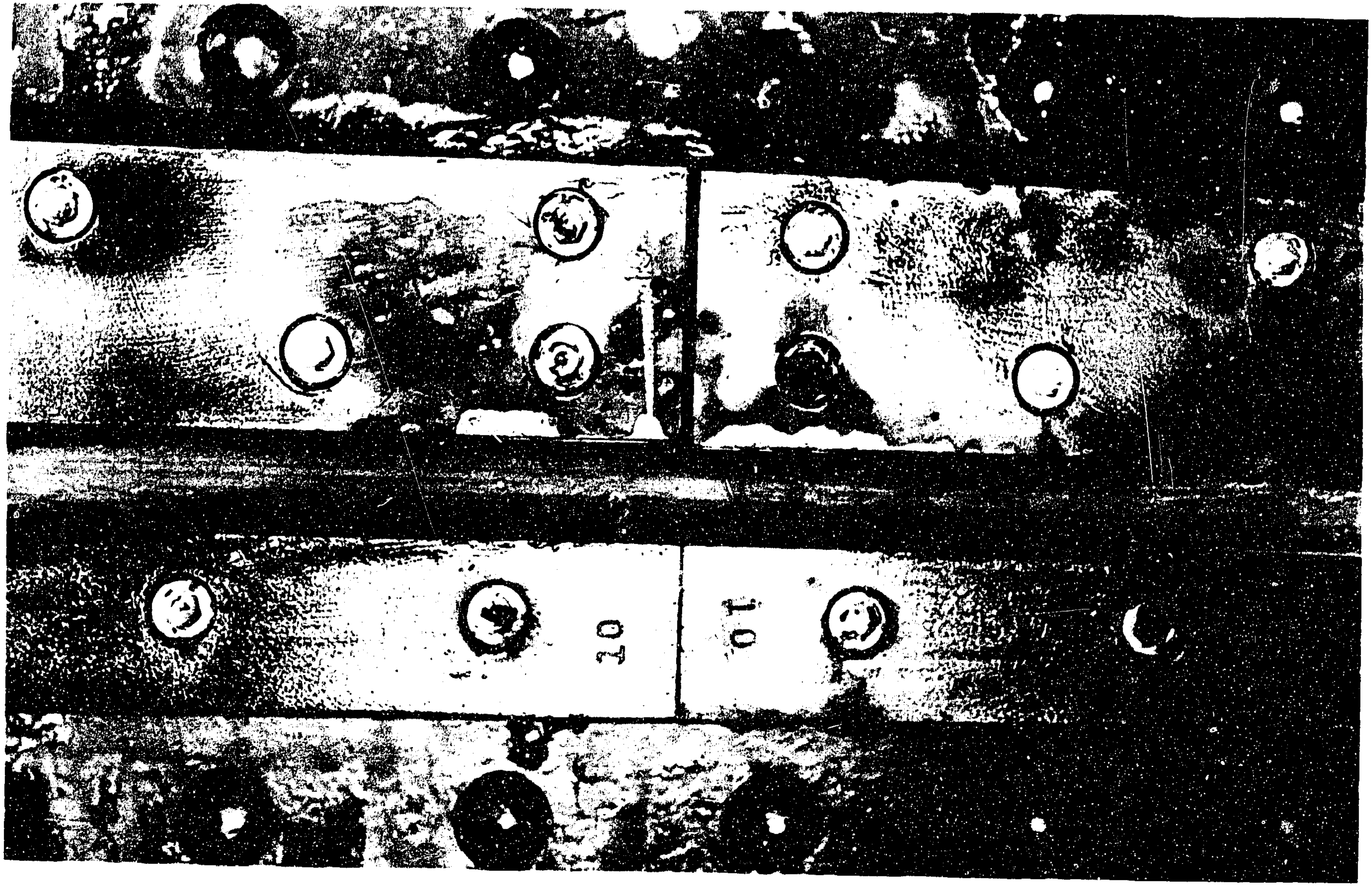
The coaster gate, formerly installed in Unit L-3, is shown installed in the R-6 penstock. The gate is equipped with the experimental seal (Reference Drawing No. 222-D-15067). Total leakage past the gate was estimated to be 25 gallons per minute. The bottom half of the gate is shown in the photo. September 20, 1950.



This closeup view of the coaster gate in the R-6 penstock was taken looking toward the left side of the gate just above the bottom to intermediate leaf section splice plate (see Photo No. 3-22848). The light colored strip on the left is the brass seal seat. The experimental seal (Reference Drawing No. 222-D-15067) is just barely visible in the 5/16" wide recess between the seal seat and seal clamp. September 20, 1950.

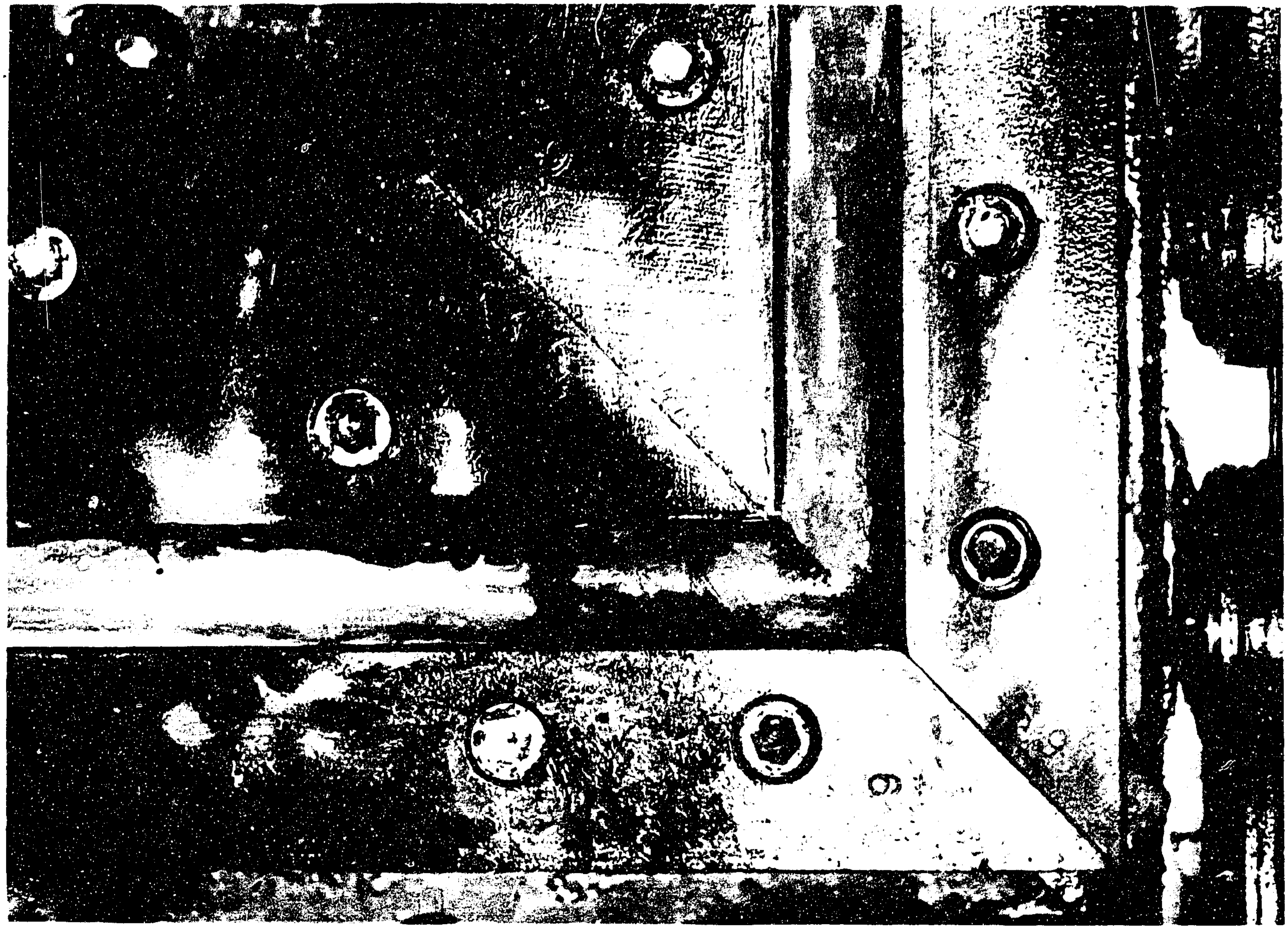


The special rubber seal (Drawing No. 222-D-14970) is shown on the R-6 coaster gate after completion of the simulated emergency closure tests. The photo shows the condition of the lower east corner of the seal. October 11, 1950.



The special rubber seal (Drawing No. 222-D-14970) is shown on the R-6 coaster gate after completion of the simulated emergency closure tests. The photo shows the condition of the midpoint of the lower seal. October 11, 1950.

Report Hyd. 311 Photo No. 3-22985



Report Hyd. 311 Photo No. 3-22986

The special rubber seal (Drawing No. 222-D-14970) is shown on the R-6 coaster gate after completion of the simulated emergency closure tests. The photo shows the condition of the lower west corner of the seal. Note the space between the lower clamp bar and the seal. October 11, 1950.

Report Hyd. 311 Photo No. 3-22987

The special rubber seal (Drawing No. 222-D-14970) is shown on the R-6 coaster gate after completion of the simulated emergency closure tests. The photo shows the upper west corner of the seal. The pulled down condition of the seal at the corner was present before the tests and does not appear to have been altered during the tests. October 11, 1950.