UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC LABORATORY TESTS OF SEALS FOR RADIAL GATES

Hydraulic Laboratory Report No. Hyd-323

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

January 23, 1952

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Design and Construction Division
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January 23, 1952

Laboratory Report No. 323
Hydraulic Laboratory
Written by: W. C. Case
Reviewed by: J. W. Ball

Subject: Hydraulic Laboratory tests of seals for radial gates

PURPOSE

To investigate the operating characteristics of radial gate rubber seal designs.

CONCLUSIONS

1. Fabric-reinforced rubber belting is unsuitable for radial gate side seals because when the belting is assembled to the curvature of a gate (Figure 6), the lateral thrust on the wall plate (seal seat) is high (Figure 7) which results in excessive frictional drag (Figure 8A).

2. Rubber belting with a brass shoe added to reduce frictional drag on the wall plate is also unsuitable. The seal shoe assembly tested (Figures 5, 9A and 10A) was heavy, 14.8 pounds per linear foot of seal, the lateral thrust on the wall plate was very high (Figure 11), the frictional drag of the seal was high (Figure 8B), and the seal assembly did not slide easily upstream on the wall plate when the test gate was shifted nearer the wall plate which resulted in seal buckling (Figure 10B).

3. A belt-type seal molded angle shape with a brass shoe (Figures 9B and 12) is an improvement over the flat belting seal referred to in Conclusion No. 2. The friction drag on the wall is less (Figure 8C) and the seal assembly is lighter weight. The brass shoe tested did not slide easily upstream on the wall plate and the seal behavior was only fair.

4. The best side seal tested was an all rubber seal used by the Army Engineers.

(a) This seal was angle-shaped without fabric reinforcement. The fabric reinforcement shown in the design on Figure 13A appears unnecessary.

(b) The addition of the brass bar, as shown in Figures 13B and 19, reduces the friction drag (Figure 8E) but also eliminates the desired rubber-to-metal (side wall plate) sealing surfaces. Whether or not the brass bar is used at a particular installation will depend, among other things, upon the amount of permissible friction drag and whether seal leakage will cause undesirable wetting or staining of adjacent parts of the structure.

(c) The head at which sealing and unsealing took place was moderately low. Values are given in Figure 15.

(d) When this seal was compressed between flat clamp plates, the sealing surface moved to increase the angle between the seal legs (Figure 20).

(e) Other brass-bar arrangements were attached to this seal with slight alteration to provide a rubber sealing lip (Figures 21 and 22), but none proved satisfactory for reasons given later in this report

5. The one radial gate bottom seal design tested was satisfactory (Figures 2 and Part 2, Figure 14). This rectangular seal is more likely to form an effective seal at surface irregularities in the sill plate (seal seat) when the seal is made of soft rubber, Shore Type A Durometer 38, than when made of harder rubber, Shore Type A Durometer 69. The force required to compress the seating edge of this seal is given in Figure 29.

RECOMMENDATIONS

Conduct further tests on the radial gate side seal to develope a seal with low frictional drag and with rubber-to-metal (side wall plate) sealing surfaces, such as the suggested seal shown in Figures 8H and 26.

ACKNOWLEDGMENTS

The personnel in the Mechanical Branch and the Hydraulic Laboratory of the Engineering Laboratories Branch collaborated in conducting the limited investigation of radial gate seals discussed in this report.

INTRODUCTION

The Bureau uses a large number of radial gates for controlling flow in open channel spillways where heads are relatively low. These gates are provided with seals along the sides and bottom edges. The seals are usually clamped to the gates with metal spacers to permit tightening of the clamp plate bolts holding the seal in place (Figure 19). A typical gate and seals are shown on Figures 1 and 2.

The tests described in this report concern a limited study made on radial gate seals during an investigation of high head seals for coaster and fixed-wheel types of gates which has been reported in Hydraulic Laboratory Report No. Hyd-311. The test equipment used was designed specifically for the high head-gate seal tests, and required only minor modifications for the hydraulic tests on the radial gate seals. Since no testing had been done in the Hydraulic Laboratory on radial gate seals this test rig offered an opportunity for conducting brief tests on this type of seal although the rig did not represent the best arrangement for such tests. All the radial gate seal samples were supplied through the Mechanical Branch.

DESCRIPTION OF TEST EQUIPMENT

The test rig used for conducting the hydraulic tests on radial gate seals is shown on (Figures 3 and 4). To obtain the best view of a side seal in the rig window space available, a different seal back plate and window arrangement from that used for the high head seal tests was installed. The steel back plate was made of 3/4-inch instead of 1-1/2-inch steel as shown in Figure 4A, and the plate was located farther downstream. Thus, the windows permitted a view of a larger area. Each window fitted into a slot in the steel back plate, and the upstream face of the window was shouldered to fit in the rig frame. The windows were compressed between the rig frame and steel back plate by means of two 5/8-inch tie bolts outside each window. The bottom face of each window was attached to the rig floor with four machine screws to assure a watertight seal at these parting surfaces. Thus, the windows were free of the downstream movement of the back plate due to the water load which made the window assembly durable. The test gate was operated by a hydraulic jack which, in turn, was actuated by a portable, electric, motor-driven oil pump (Figure 4B). The rig sheet metal hood deflected the water to the laboratory channel below the floor level. The hood attachment was arranged for quick removal by loosening four nuts which held four steel cable ties. The rig was connected to a 12-inch water supply pipe by a circular-to-rectangular transition. The assimilated reservoir head was read on the large Bourdon gage tapped into the 12-inch pipe. Maximum water head available in the laboratory was 195 feet. All seals tested were full-size sections 12 inches long.

Sliding of the side seal on the wall plate, which corresponds to the radial gate opening or closing, was not possible with this equipment. The side seal could be moved by the test gate in a direction normal to the wall plate. This movement corresponded to the sidewise movement of a field gate. Opening and closing of a gate bottom seal was assimilated with this test equipment.

Seal water leakage was not easily determined, but the exact values of leakage were not required. When the seal seated, the combined leakages of the seal and rig (past windows, gate leaf, etc.) were too small to be conveniently measured. Visual observations of the seal-to-seat leakage sufficed for these tests.

RADIAL GATE SIDE SEAL TESTS

Belt Type Seal Without Brass Shoes

The Mechanical Branch proposed using a seal made from rubber belting. A 15-foot long sample of 3/8- by 18-inch, fabric-reinforced, rubber belting was obtained for test. A seal 8 inches wide and 15 feet long was cut from the sample and assembled in a wooden mock-up of the clamp plates similar to Trenton Dam's radial gate (Figure 5). The purpose of the mock-up was to determine any assembly difficulties of this seal. The belting was assembled first without the shoes (Figure 6), and no difficulties were encountered. The lateral thrust per linear foot at various seal positions was determined with no water load on the seal. The results are shown in Figure 7. The thrust was determined by lifting the seal up and off the laboratory floor with a spring scale and a steel bar placed under and perpendicular to the seal axis--all arranged as a second-class lever with the floor representing the wall plate. The seal was lifted at a point midway between two pieces of paper placed 12 inches apart on the floor under the seal. When the paper could be slipped by hand, (thrust load on floor relieved) the spring-scale load was recorded, and the thrust computed. The lateral thrust was high and, with the addition of water load on the seal, the resulting seal friction with the side wall plate (seat) would require considerable power to operate the gate. The approximate frictional drag of the seal on the wall plate is 75.1 pounds per inch of seal at a 40-foot head and zero seal gap, (zero gap defined in Figure 5), as shown in the computation in Figure 8A. In view of the high drag, no hydraulic tests were justified. It was decided to investigate the same seal with the brass shoes bolted to the belting (Figure 9A) to reduce the frictional drag of the seal on the wall plate.

Belt Type Seal With Brass Shoes

The belt seal with shoes was also assembled in a wooden mock-up (Figure 10A), using wooden shoes as shown in Figure 5. The wooden shoes were first bolted to the seal with the seal (belting) straight. The seal was then bolted to the 40-foot radius wooden form representing the gate edge. Due to the added stiffness, the seal was somewhat more difficult to bolt to the 40-foot radius than the seal without the shoes. Tests were made to determine the lateral thrust in pounds per linear foot of seal (Figure 11), and the thrust was much higher than the same seal without the shoes. Even though the lateral thrust of the seal was higher with the brass shoes, the seal friction on the side wall plates was less, as illustrated by the computation shown in Figures 8A and 8B.

Hydraulic tests in the rig over the laboratory head range of zero to 190 feet of water showed that when the gate was moved away from the wall plate (rig floor) the seal shoe slid downstream and remained in flat contact with the wall plate. However, when the gate was moved nearer to the wall plate, the brass shoe would not slide upstream on the wall plate, and the rubber belting buckled (Figure 10B). The heel of the brass shoe, point Y, Figure 5, lost contact with the wall plate when the seal gap was 9/16-inch (distance x = 1-5/16 inches, Figure 11), and this value was essentially independent of the reservoir head. The seal behavior was considered unacceptable. The seal weight was high, 14.8 pounds per linear foot.

Molded Type Belt Seal

As a means of reducing the lateral thrust of the belt type of seal, the Mechanical Branch proposed that the belt seal be molded to the shape shown on Figure 12. The approximate frictional drag of a molded seal at 40-foot head and zero gap is considerably less than the belt seal (Figures 8B and 8C). Sufficient length of such a seal was not available for lateral thrust determinations in the wooden mock-up. It was decided to take the fabric-reinforced angle seal (Figure 13A) and machine it to 3/8-inch thick. The finished seal with brass shoe, shown in Figure 9B, weighed 3.6 pounds per linear foot. Machining of the rubber was difficult, and an irregular seal edge was obtained.

At a 40-foot head the brass shoe did not slip upstream freely as the seal gap was decreased from 3/8 to zero inch; however, the shoe did move slowly. The seal buckled at 1/4-inch negative gap, and the sealing lip raised slightly from the seat (rig floor). It was possible, while decreasing the seal gap, to cause the upstream clamp plate to contact the heads of the shoe attaching screws, because the shoe was slow to move upstream. The heel end of the seal shoe, point Y, Figure 12, lost contact with the seat when the seal gap reached 3/8 inch. It was concluded the seal operation was only fair.

Angle Seal Without a Brass Bar

Two designs of radial gate side seal used by the Army Engineers' were available for test; one, an all-rubber seal like that shown as Part 1, Figure 14, and the other similar to it, except fabric reinforced (Figure 13A). Each weighed about 2.5 pounds per linear foot. The seal in Figure 14, Part 1 evolved from the laboratory tests is intended for field use. This seal incorporates a slightly larger angle between the seal legs than the seal used by the Army Engineers. Figure 15 shows the head required to seal and unseal the all-rubber seal for gaps from zero to 1/2 inch. At 1/2-inch gap, the water head required for sealing was 22 feet, while that at which unsealing occurred was 8 feet. The maximum seal gap intended during gate operation is approximately zero.

Figure 16 shows the head required to seat and unseat the heel end of this seal for seal gaps from zero to 1/2 inch. In general, the head required was higher than encountered with radial gates. The lower leg of the seal flattened to an undesirable curved shape (Figure 17). A seal that has been installed several years may take this shape at a much lower head. The bolted leg of this seal stretches considerably, as shown by the dimension "S" of Figure 16. The frictional drag of this seal on the wall plate is likely to be high in comparison to other designs as shown in Figure 8D; otherwise, the behavior of this seal was good, and it provided the desired rubber-to-metal sealing surfaces.

Figure 18 shows the head at which sealing and unsealing of fabric-reinforced seal occurred for seal gaps from zero to 1/2 inch. The fabric-reinforced seal is much stiffer than the all-rubber seal, as indicated by the note on Figure 16. The laboratory tests revealed no reason for needing the fabric reinforcement.

Angle Seal With Brass Bar Designs

Brass bars, or shoes, were added to the angle seal to reduce the frictional drag. One such design, weighing 3.4 pounds per linear foot, is shown in Figures 13B and 19. The estimated frictional drag of this seal on the wall plate is low (Figure 8E) compared to other seal designs. Figure 15 shows the head at which sealing and unsealing occurred at gaps from zero to 1/2 inch. The added brass bar weight and possible changed flow conditions under the sealing surface resulted in a slightly lower sealing and unsealing head compared to the all-rubber seal. However, it is intended that the seal be assembled with a 1/4-inch initial deflection (negative gap) as shown in Figure 19 to assure a seal at very low heads near the top of the gate. With this 1/4-inch lateral gate movement possible (Figure 2, Section D-D), the side seal could possibly be deflected 1/2 inch. With these conditions, the heel end of the seal should clear the wall plate by approximately the thickness of the brass bar, 3/16 inch (Figure 19). This clearance was determined from dimensions of the seal intended for field use (Figure 14, Part 1). If the heel end of the seal rubs on the wall plate, it is likely to cause excessive gate drag. At the higher heads, the lower leg of this seal with a brass bar took a more severe curved shape than without the bar. Based on visual observations, the angle seal with the brass bar (metal-to-metal seal) leaked only slightly more than the all-rubber seal. Whether or not the brass bar is used will depend, among other things, upon the amount of permissible frictional drag and whether seal leakage will cause objectionable stains or algae growth on adjacent parts of the structure.

The movement of the seal surface due to clamp plate loads was investigated. It was not certain whether the sealing surface would move inward or outward when the seal stem was compressed between the clamp plates. The clamp plate load was applied by a Materials Laboratories' testing machine, as shown in Figure 20. Four dial indicator gages were used; three to measure the sealing surface movement and one to measure the compression of the seal stem under load. The sealing surface moved outward, increasing the angle between the seal legs. The results, shown on Figure 20, are not conclusive because the seal toe movement was based upon approximately a 1-foot length of seal clamped flat, which does not consider the effect of the seal clamped to a large radius, such as 40 feet. Since the angle between the seal legs is greater than 90° (Figure 14, Part 1), it is conjectured that clamping the seal to a large radius, with no seal contact on the wall plate, will also tend to make the seal toe move outward, the same direction as shown on Figure 20.

Two seals were made that included rubber-to-metal sealing surfaces and a brass member to reduce the frictional drag (Figures 21 and 22). Both were reworks of the all-rubber angle seal design used by the Army Engineers. The seal flap (Figure 21A) was intended to be a single piece, but rubber sheeting of the preferred thickness was not available so two thicknesses were cemented together. This seal was generally unsatisfactory at the lower heads, as the flap did not make contact with the seat (rig floor). The head required to obtain a seal was high (Figure 23). When the flap was in contact with the seat, the sealing was good. At the higher head, when the lower leg curved due to the greater pressure, the flap was lifted off the seat. The head at which this condition occurred at various gaps is shown in Figure 23. The estimated frictional drag of this seal on the wall plate is 13.0 pounds per inch of seal at 40 feet of head and zero gap (Figure 8F). The seal weight per linear foot was 3.6 pounds.

The seal shown in Figures 21B and 22 incorporated a more stabilized sealing lip. This seal was made from a 12-inch section of the all-rubber angle seal. A 2-1/2- by 3/16-inch brass plate was bolted to the seal to minimize the frictional drag, especially high drag at negative seal gaps. The head required to seal and unseal this seal is shown in Figure 24, and the results are comparable to those for the all-rubber angle seal with and without the brass bar (Figure 15). Operation of the seal at small gaps, less than 1/8 inch, was good, because the rubber sealing lip carried a small portion of the seal water load. The seal operation was only fair at the larger seal gaps, to 1/2 inch, because the rubber seal lip carried a greater portion of the water load, thereby increasing the drag (Figure 25). However, the maximum seal gap that is likely to occur in the field is estimated to be zero. The frictional drag at 40-foot head and at zero gap is approximately 11.2 pounds per inch length of seal (Figure 8G). This seal weighed 4.2 pounds per linear foot.

Future Side Seal Investigations

It appears from the foregoing, particularly the information on Figure 8, that a side seal design should include the features listed below. A suggested design incorporating these features is shown in Figure 26.

(a) Near the top of the gate where the head is low the sealing force of the seal should be independent of the water head. A satisfactory way to accomplish this may be to assemble the angle type seal to the gate with 1/4-inch initial deflection of the seal against the wall plate.

(b) A rubber-to-metal (wall plate) seal is desired to obtain the least water leakage at the lower heads near the top of a gate.

To minimize the frictional drag of the rubber member, the water load carried by this member must be low, or negligible, and the sealing force obtained primarily from the initial deflection of seal as stated in (a) above. A metal-to-metal seal is undesirable because leakage might cause unsightly side wall stains or algae growth.

(c) The heel end of the seal should not be permitted to contact the wall plate because this would increase the frictional drag of the seal. Therefore, the seal water load at the heel end should be carried by the gate. Also, the lateral movement of the gate should be limited so that the heel end of the seal cannot rub on the wall plates.

(d) The seal area that is exposed to the water load should be as small as possible to reduce the seal water load to a minimum to keep the frictional drag of the seal low; however, this area must not be so small that an inadequate sealing force is provided by the water. The 1-1/2-inch dimension in Figure 26 appears sufficient.

(e) The major portion of the seal water load onto the wall plates should be carried through a metal member to minimize the frictional drag of the seal. The extra strong 1/4-inch brass pipe shown in Figure 26 has the advantage of being a commercial part not specially made. The drilled holes in the brass pipe should assure a good bond to rubber and thus eliminate bolting of the brass member to the seal. The brass pipe can be the same length as the molded seal sections. The pipe can be curved very slightly at field installation to fit the curvature of the gate. Joints in the brass member approximately every 2 feet as shown in Figure 19 could thus be eliminated. If the brass member is omitted, the all-rubber sealing surface results in a high seal frictional drag (Figure 8D).

(f) At the higher heads, it is desirable to relieve the force of the rubber seal lip on the wall plate to alleviate the frictional drag of the rubber lip. The short leg of the seal in Figure 26 will turn counterclockwise slightly about the brass pipe which gives the desired action. At the higher heads, the brass pipe alone is likely to provide a satisfactory seal.

The estimated frictional drag of the seal in Figure 26 is 6.0 pounds per linear inch of seal at 40 feet of head and zero gap (Figure 8H). This drag is low compared to other seal designs shown on Figure 8, particularly that shown on Figure 8E, which does not incorporate a rubber sealing lip.

RADIAL GATE BOTTOM SEAL TESTS

The test rig was again modified as shown in Figure 27. The angle iron seal seat included a circular cut, 3/32 inch deep at the seat center line and 3 inches wide, to represent a depression in the metal seating surface (sill plate). The angle of the seal seat relative to the seal was similar to that of a field gate (Figure 2). Two all-rubber seal samples were available for test; each one was rectangular in section (Part 2, Figure 14). One was made of stock with a Type A Shore Durometer hardness of 69. The other sample was made of stock with a Type A Shore Durometer hardness of 38.

Both seal samples were tested in the rig at heads of zero to 195 feet of water. Both seals appeared to seal satisfactorily. At the higher compressions of the soft rubber seal, it deformed under the upstream clamp plate (Figure 28A). Based on visual observations, a better seal was obtained by extending the upstream clamp plate as shown in Figure 27. At heads of 55 or more feet, the soft rubber seal had a tendency to sweep under the downstream clamp plate (Figure 28B).

The principal test conducted on these two seal samples was to determine the force required to compress the seal. This information was obtained on a universal-type testing machine in the Materials Laboratories. A plot of the compression on the seal in inches versus the compression force, pounds per foot of seal for wet and dry seats, is shown for both seal samples in Figure 29. The wet seal seat data were obtained by submerging the seal seat (angle iron) in a pan of water. The force required to seal the 3/32-inch deep cut for the hard-rubber seal was 140 pounds per foot of seal, whereas the force for the soft seal was 40 pounds. These data were desired for gate design purposes to assure sealing of depressions in the seal seat (sill plate).

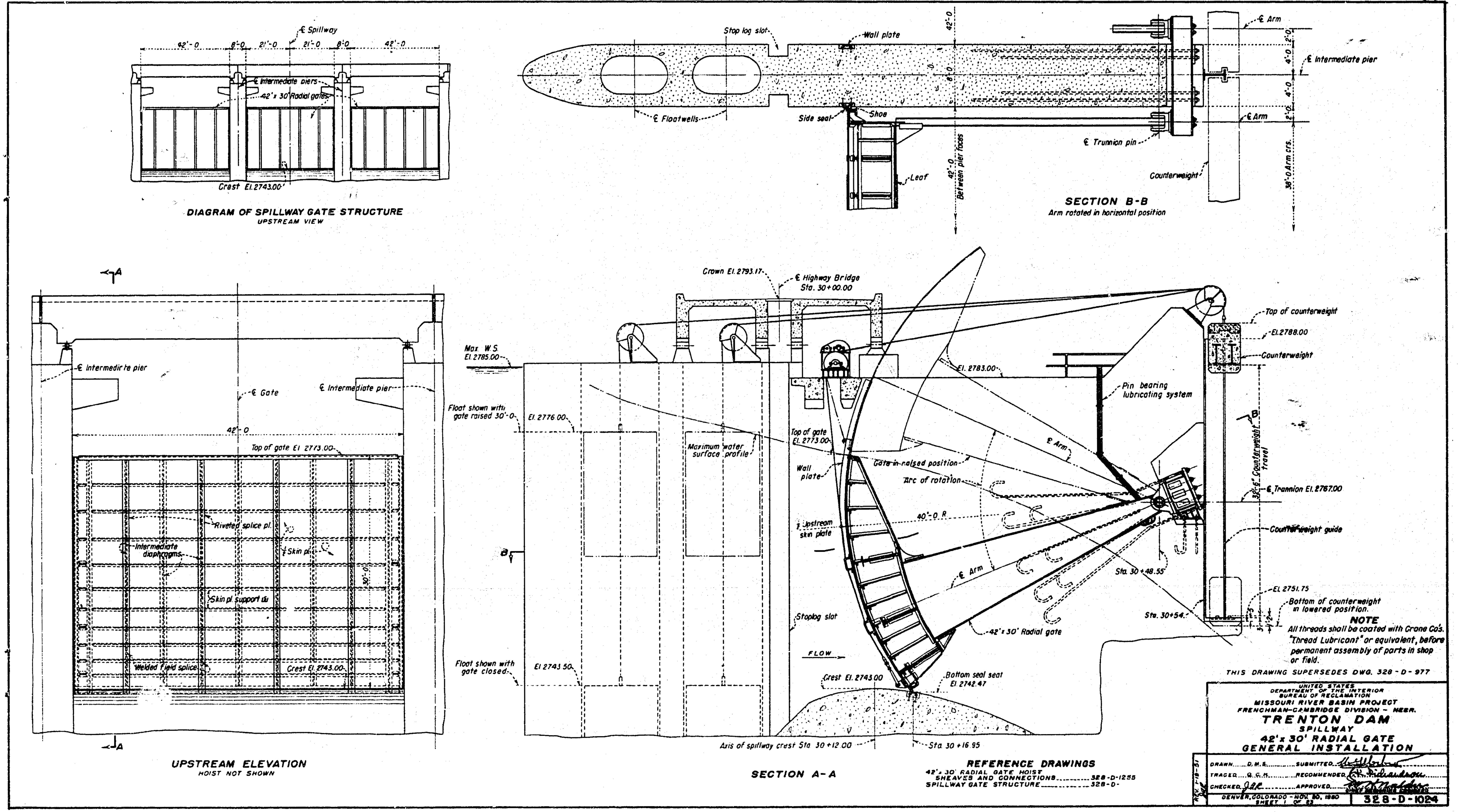
℄ Spillway
42'-0 8'-0 21'-0 21'-0 8'-0 42'-0
℄ Intermediate piers
42' x 30' Radial gates
Crest El. 2743.00
DIAGRAM OF SPILLWAY GATE STRUCTURE
UPSTREAM VIEW
Stop log slot
Wall plate
℄ Floatwells
Side seal
Shoe
Leaf
42'-0 Between pier faces
℄ Arm
℄ Intermediate pier
℄ Trunnion pin
Counterweight
38'-0 Arm crs.
SECTION B-B
Arm rotated in horizontal position
℄ Intermediate pier
℄ Gate
℄ Intermediate pier
42'-0
Top of gate El 2773.00
Riveted splice pl.
Intermediate diaphragms
Skin pl.
Skin pl. support
30'-0
Welded field splice
Crest El. 2743.00
UPSTREAM ELEVATION
HOIST NOT SHOWN
Crown El. 2793.17
℄ Highway Bridge Sta. 30+00.00
Max. W.S. El. 2785.00
Float shown with gate raised 30'-0
El. 2776.00
Maximum water surface profile
El. 2783.00
Top of gate El. 2773.00
Wall plate
Gate in raised position
Arc of rotation
℄ Arm
Pin bearing lubricating system
Top of counterweight
El. 2788.00
Counterweight
32'-6" Counterweight travel
℄ Trunnion El. 2767.00
40'-0 R.
Upstream skin plate
Counterweight guide
℄ Arm
Sta. 30+48.55
El. 2751.75
Bottom of counterweight in lowered position.
Sta. 30+54
Stoplog slot
42' x 30' Radial gate
FLOW
Float shown with gate closed
El. 2743.50
Crest El. 2743.00
Bottom seal seat El. 2742.47
Axis of spillway crest Sta. 30+12.00
Sta. 30+16.95
SECTION A-A
NOTE
All threads shall be coated with Crane Co's. "Thread Lubricant" or equivalent, before permanent assembly of parts in shop or field.
THIS DRAWING SUPERSEDES DWG. 328-D-977
REFERENCE DRAWINGS
42' x 30' RADIAL GATE HOIST SHEAVES AND CONNECTIONS 328-D-1255
SPILLWAY GATE STRUCTURE 328-D-
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
FRENCHMAN-CAMBRIDGE DIVISION - NEBR.
TRENTON DAM
SPILLWAY
42' x 30' RADIAL GATE
GENERAL INSTALLATION
DRAWN D.M.S. SUBMITTED
TRACED G.C.H. RECOMMENDED
CHECKED APPROVED
DENVER, COLORADO - NOV. 30, 1950 SHEET 1 OF 33
328-D-1024

FIGURE 2
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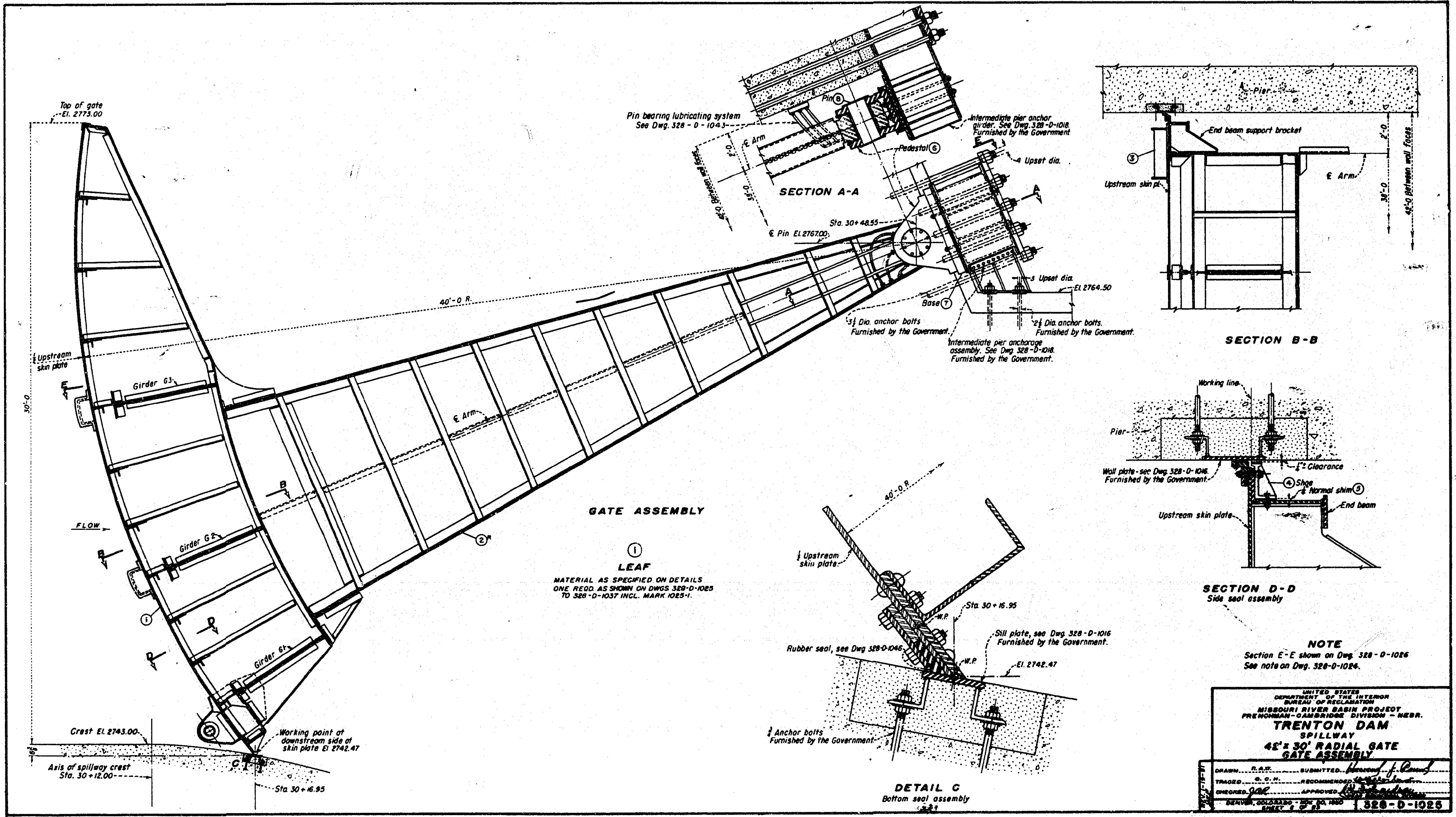


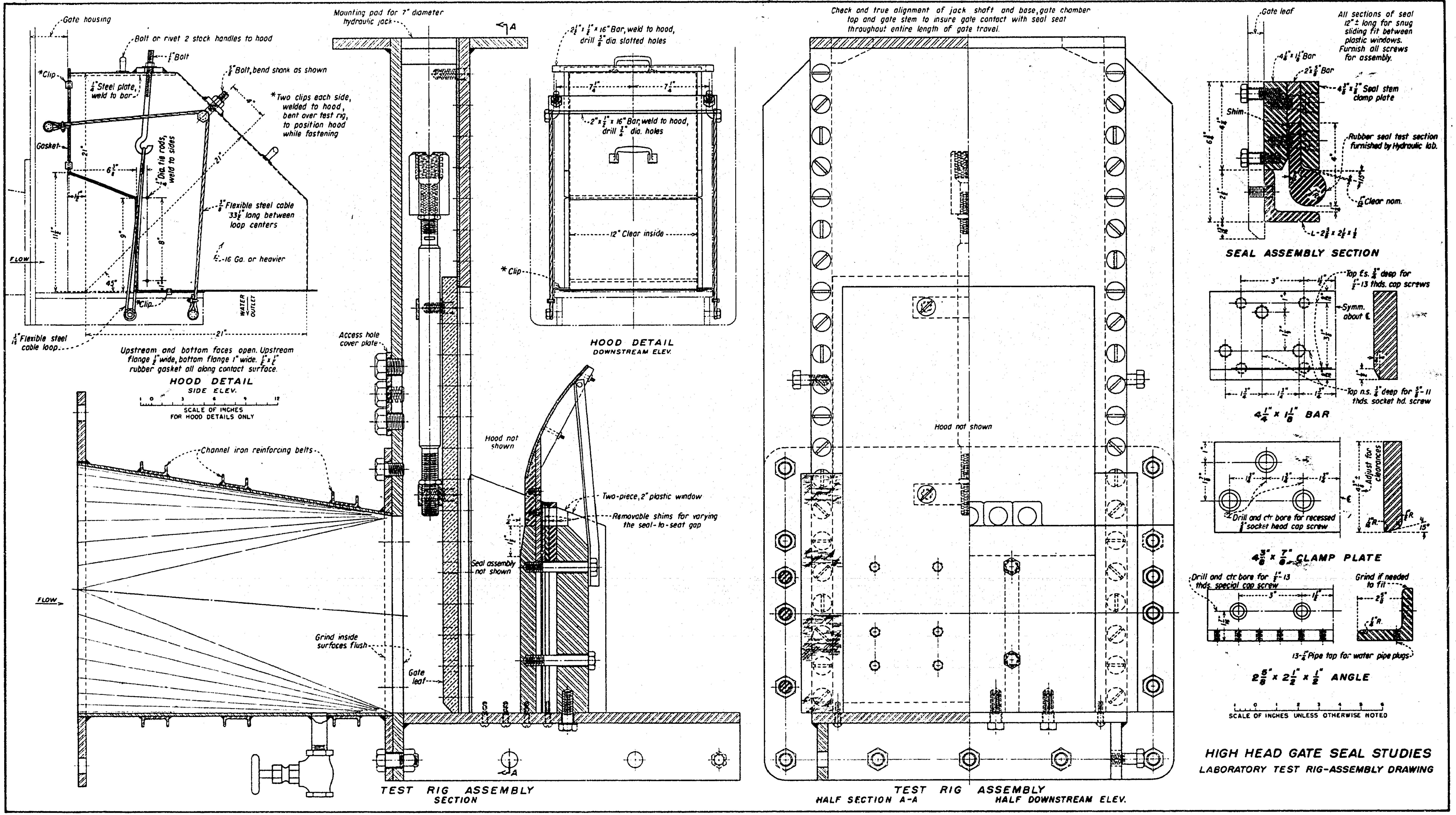
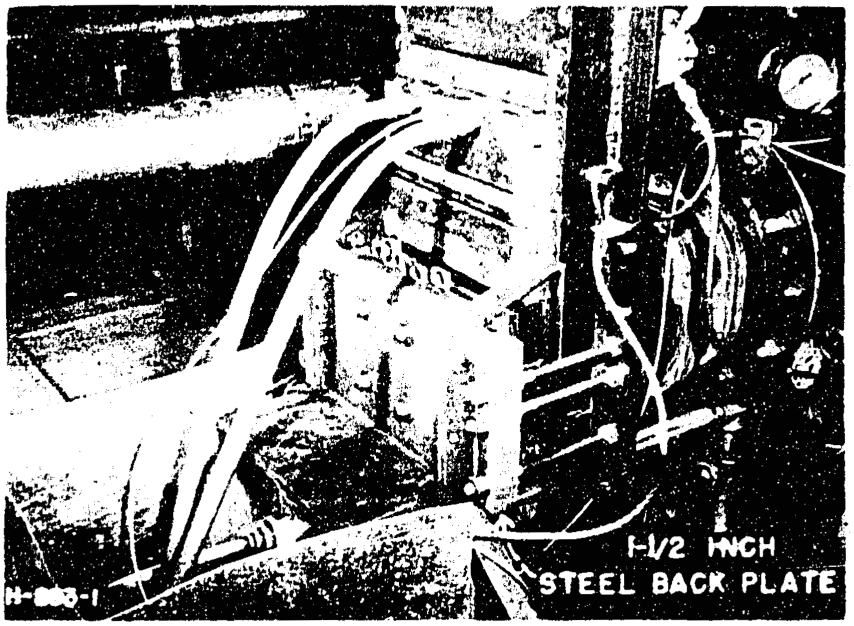
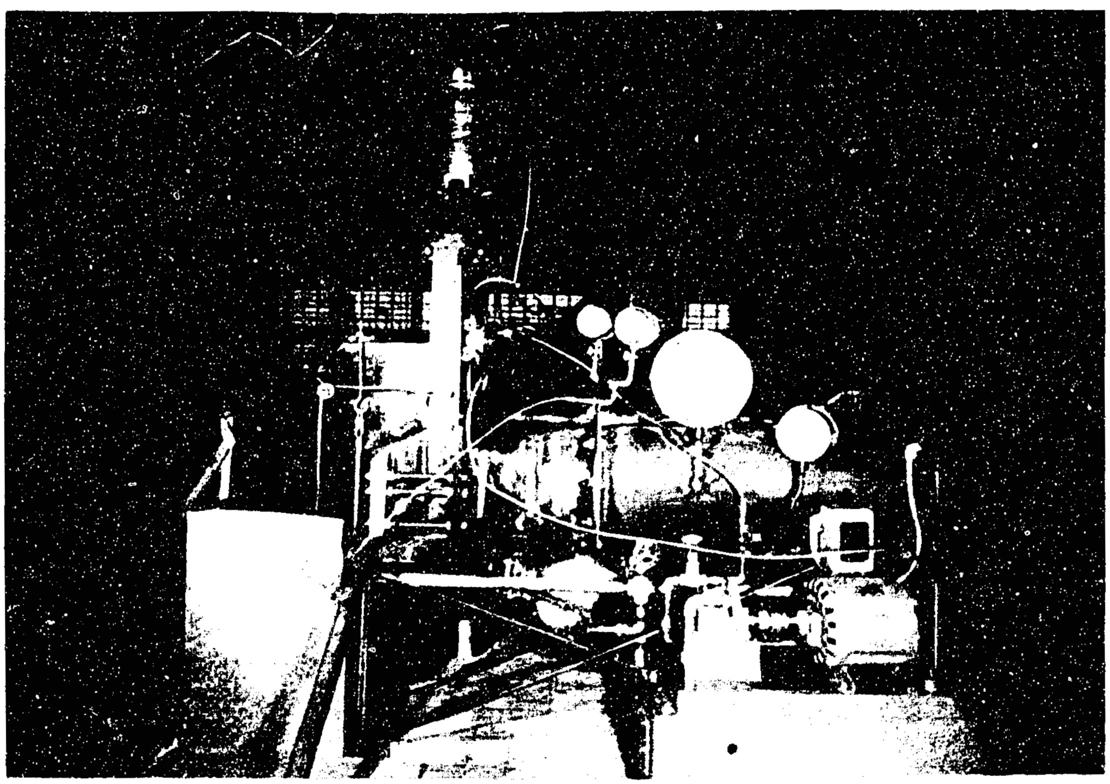

Gate housing
Bolt or rivet 2 stock handles to hood
*Clip
1/4" Steel plate, weld to bar
Bolt
Bolt, bend shank as shown
*Two clips each side, welded to hood, bent over test rig, to position hood while fastening
Gasket
Dia. tie rods, weld to sides
Flexible steel cable 33 1/2" long between loop centers
16 Ga. or heavier
FLOW
Clip
WATER OUTLET
Flexible steel cable loop
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
Access hole cover plate
Bar, weld to hood, drill dia slotted holes
Bar, weld to hood, drill dia. holes
12" Clear inside
*Clip
HOOD DETAIL
DOWNSTREAM ELEV.
Channel iron reinforcing belts
Hood not shown
Two-piece, 2" plastic window
Removable shims for varying the seal-to-seat gap
Seal assembly not shown
Grind inside surfaces flush
Gate leaf
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.
Gate leaf
All sections of seal 12" ± long for snug sliding fit between plastic windows. Furnish all screws for assembly.
Bar
Seal stem clamp plate
Shim
Rubber seal test section furnished by Hydraulic lab.
Clear nom.
SEAL ASSEMBLY SECTION
Tap f.s. deep for 13 thds. cap screws
Symm. about ℄
Tap n.s. deep for 11 thds. socket hd. screw
4 1/4" x 1 1/8" BAR
Adjust for clearances
Drill and ctr bore for recessed socket head cap screw
4 3/8" x 7/8" CLAMP PLATE
Drill and ctr bore for 13 thds. special cap screw
Grind if needed to fit
13 Pipe tap for water pipe plugs
2 5/8" x 2 1/2" x 1/2" ANGLE
SCALE OF INCHES UNLESS OTHERWISE NOTED
HIGH HEAD GATE SEAL STUDIES
LABORATORY TEST RIG-ASSEMBLY DRAWING

FIGURE 4
Report Hyd-323



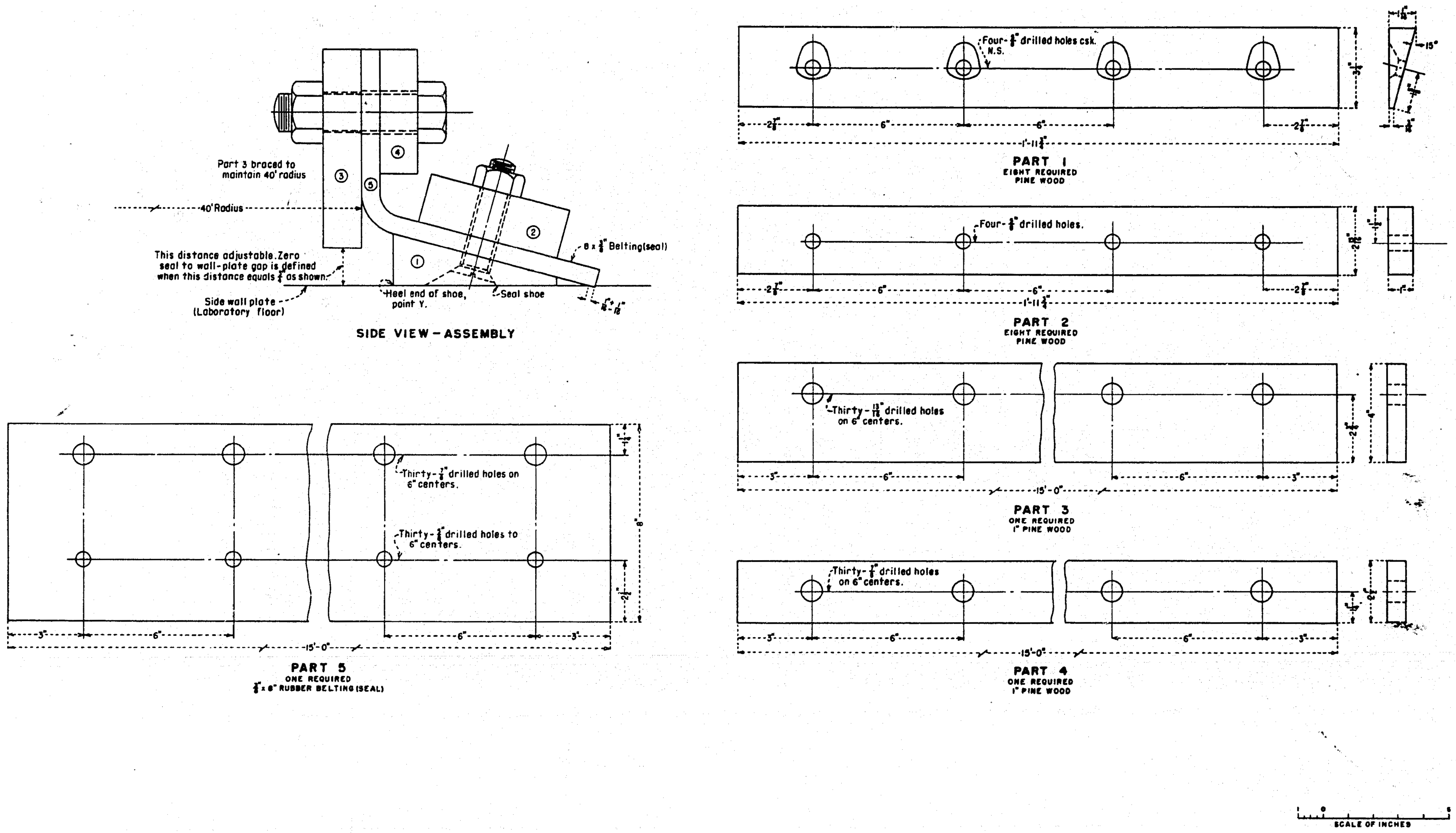
(A) Close-up view of the test rig for high head gate seal tests before the steel back-plate and window assembly were revised for the radial gate seal tests.



(B) General view of the test rig and equipment.

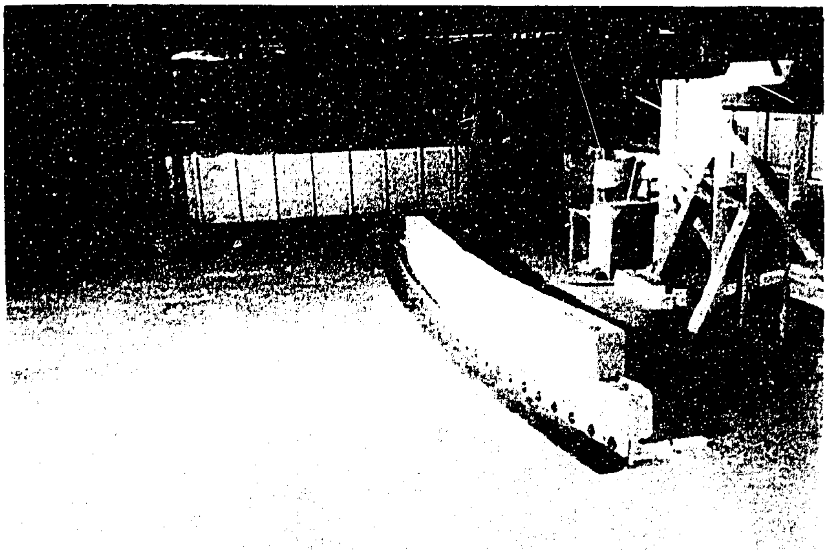
RADIAL GATE SEAL TESTS

Views of the Test Rig

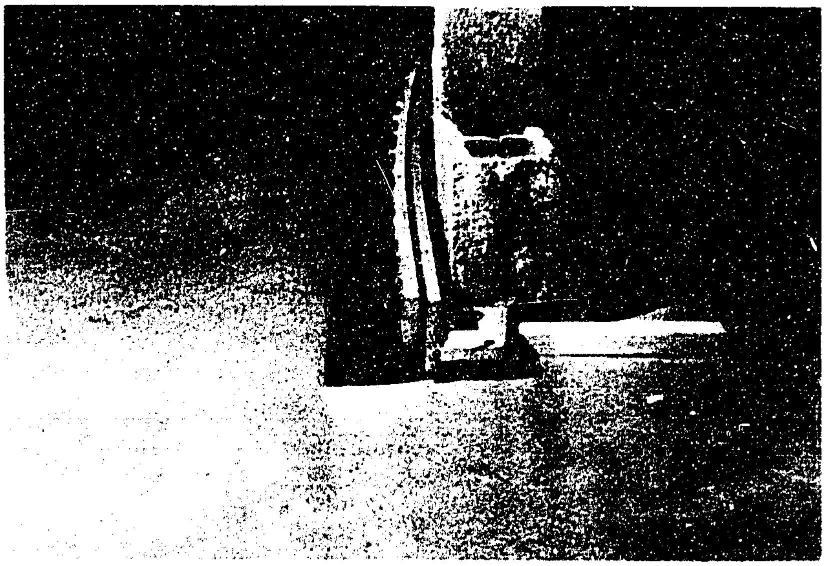


RADIAL GATE SEAL TESTS
WOODEN MOCK-UP OF RADIAL GATE SIDE SEAL MADE FROM RUBBER BELTING

415



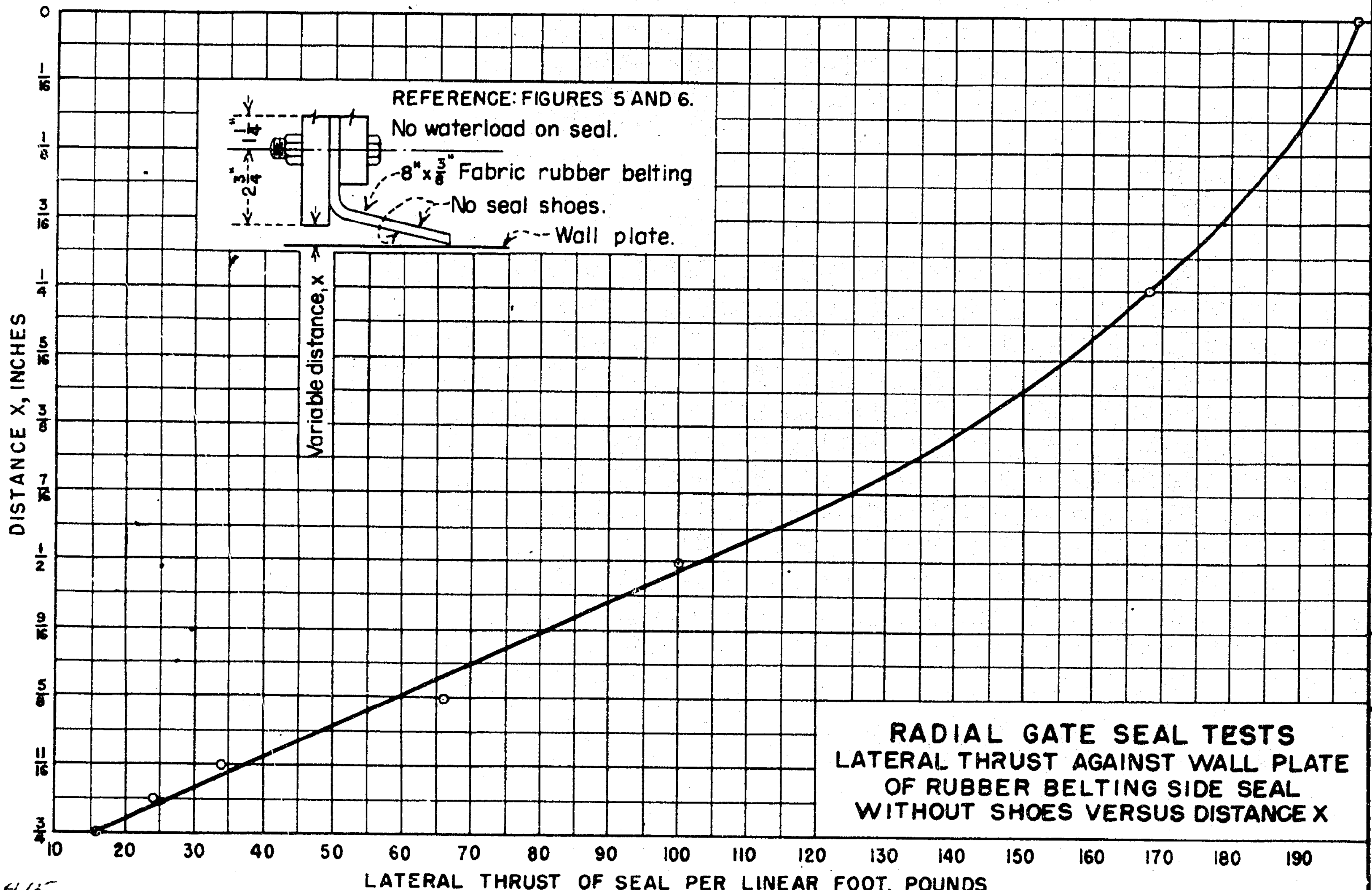
(A) General view of the 3/8 x 8 inch x 15 foot long belting seal bolted to a 40-foot radius.



(B) Close-up view of the above assembly.

RADIAL GATE SEAL TESTS

Wooden Mock-up of Rubber Belting Side Seal without Brass Shoes



RADIAL GATE SEAL TESTS

LATERAL THRUST AGAINST WALL PLATE OF RUBBER BELTING SIDE SEAL WITHOUT SHOES VERSUS DISTANCE X

Report Hyd. 323 FIGURE 7

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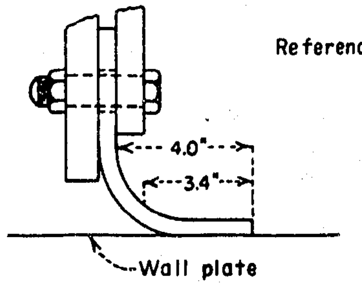
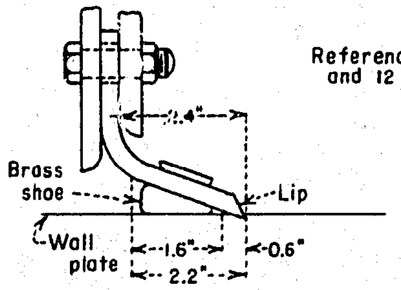


Reference, see Figure 6

W = water force on 4.0" dimension = (4.0")17.3 = 69.2 lbs./inch of seal.
R = portion of W carried by wall plate = $\frac{3.4}{4.0}$(69.2) = 58.8 lbs./inch of seal.
T = thrust force of seal on wall plate due to bent seal = $\frac{16}{12}$ lbs./inch of seal from Figure 7 = 1.33 lbs./inch of seal.
F = total force on wall plate = R + T = 58.8 + 1.33 = 60.13 lbs./inch of seal.
F' = total frictional force of seal on wall plate = f_RF = (1.25)60.13 = 75.1 lbs./ inch of seal

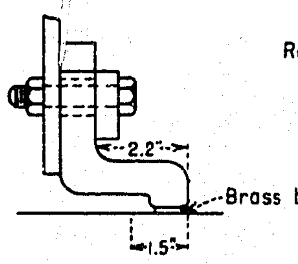
A. RUBBER BELTING SEAL WITHOUT A BRASS SHOE



Reference, see Figures 9B and 12

W = water force on 2.4" dimension = (2.4)17.3 = 41.5 lbs./inch of seal.
F = total force on wall plate = $\frac{2.2}{2.4}$W = $\frac{2.2}{2.4}$(41.5) = 38.1 lbs./inch of seal.
B = portion of F carried by brass shoe = $\frac{1.6}{2.2}$(38.1) = 27.7 lbs./inch of seal.
R = portion of F carried by rubber lip = F - B = 38.1 - 27.7 = 10.4 lbs./inch of seal.
F' = total frictional force on wall plate = f_BB + f_RR = (.25)27.7 + (1.25)10.4 = 6.92 + 13.0 = 19.9 lbs./inch of seal.

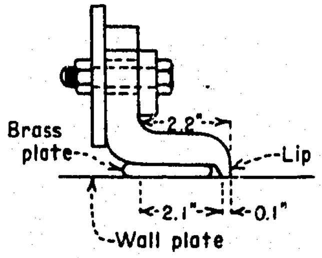
C. MOLDED BELT TYPE SEAL WITH A BRASS SHOE



Reference, see Figures 13B and 19

W = water force on 2.2" dimension = (2.2)17.3 = 38.1 lbs./inch of seal.
F = total force on wall plate = $\frac{1.5}{2.2}$(38.1) = 26.0 lbs./inch of seal.
F' = total frictional force on wall plate = f_BF = (.25)26.0 = 6.5 lbs./inch of seal.

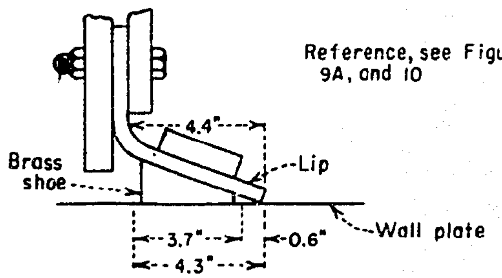
E. MOLDED ANGLE SEAL WITH A BRASS BAR



Reference, see Figures 21B and 22

W = water force on 2.2" dimension = (2.2)17.3 = 38.1 lbs./inch of seal.
F = total force on wall plate = W
B = portion of F carried by brass plate, lbs./inch of seal = $\frac{2.1}{2.2}$(38.1) = 36.4 lbs./inch of seal.
R = portion of F carried by rubber lip, lbs./inch of seal = F - B = 38.1 - 36.4 = 1.7 lbs./inch of seal
F' = total frictional force on wall plate = f_BB + f_RR = (.25)36.4 + (1.25)1.7 = 11.2 lbs./inch of seal.

G. MOLDED ANGLE SEAL WITH A BRASS PLATE

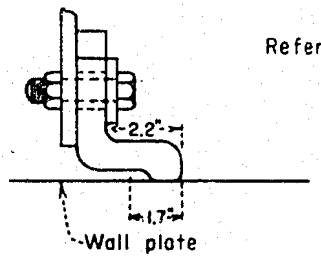


Reference, see Figures 5, 9A, and 10

W = water force on 4.4" dimension = (4.4")17.3 = 76. lbs./inch of seal.
T = thrust force of seal on wall plate due to bent seal = $\frac{158}{12}$ lbs./inch of seal from Figure 11 = 13.2 lbs./inch of seal.
F = total force on wall plate = $\frac{4.3}{4.4}$ W + T = $\frac{4.3}{4.4}$(76) + 13.2 = 87.5 lbs./inch of seal.
B = portion of F carried by brass shoe = $\frac{3.7}{4.3}$ F = $\frac{3.7}{4.3}$87.5 = 75.3 lbs./inch of seal.
R = portion of F carried by rubber lip, lbs./inch of seal = F - B = 87.5 - 75.3 = 12.2 lbs./inch of seal.
F' = total frictional force = f_BB + f_RR = (.25)75.3 + (1.25)12.2 = 34.1 lbs./inch of seal

B. RUBBER BELTING SEAL WITH A BRASS SHOE

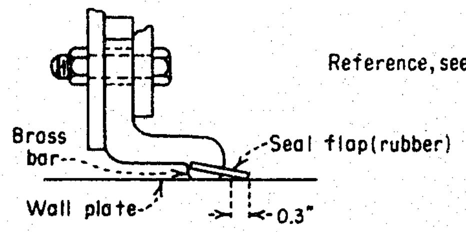
415



Reference, see Figure 13B

W = water force on 2.2" dimension = (2.2)17.3 = 38.1 lbs./inch of seal.
F = total force on wall plate = $\frac{1.7}{2.2}$(38.1) = 29.5 lbs./inch of seal.
F' = total frictional force on wall plate = f_RF = (1.25)29.5 = 36.9 lbs./inch of seal.

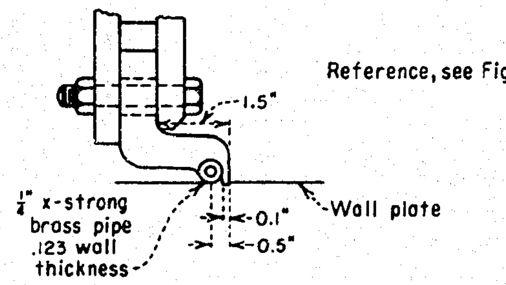
D. MOLDED ANGLE SEAL WITHOUT A BRASS BAR



Reference, see Figure 21A

Same assembly as item E, molded angle seal with a brass bar, total frictional force of 6.5 lbs./inch of seal, plus
R = water force on 0.3" dimension of seal flap = (.3)17.3 = 5.2 lbs./inch of seal.
F' = total frictional force on wall plate = 6.5 + f_RR = 6.5 + (1.25)5.2 = 13.0 lbs./inch of seal.

F. MOLDED ANGLE SEAL WITH A BRASS BAR AND A SEAL FLAP



Reference, see Figure 26

W = water force on 1.5" dimension = (1.5)17.3 = 26.0 lbs./inch of seal.
F = total force on wall plate = $\frac{1}{1.5}$(26.0) = 17.3 lbs./inch of seal.
B = portion of F carried by brass, lbs./inch of seal = $\frac{0.9}{1.0}$ F = $\frac{0.9}{1.0}$17.3 = 15.6 lbs./inch of seal.
R = portion of F carried by rubber lip, lbs./inch of seal = F - B = 1.7 lbs./inch of seal.
F' = total frictional force on wall plate = f_BB + f_RR = (.25)15.6 + (1.25)1.7 = 6.0 lbs./inch of seal

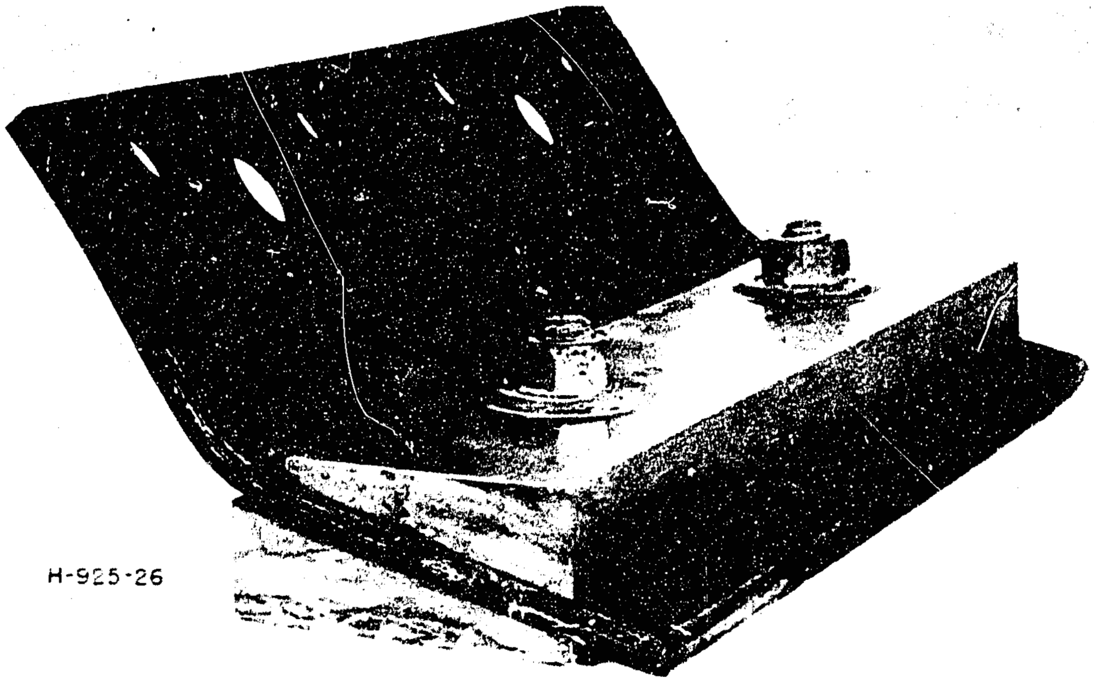
H. PROPOSED ANGLE SEAL WITH BRASS PIPE AND SEALING LIP

NOTES

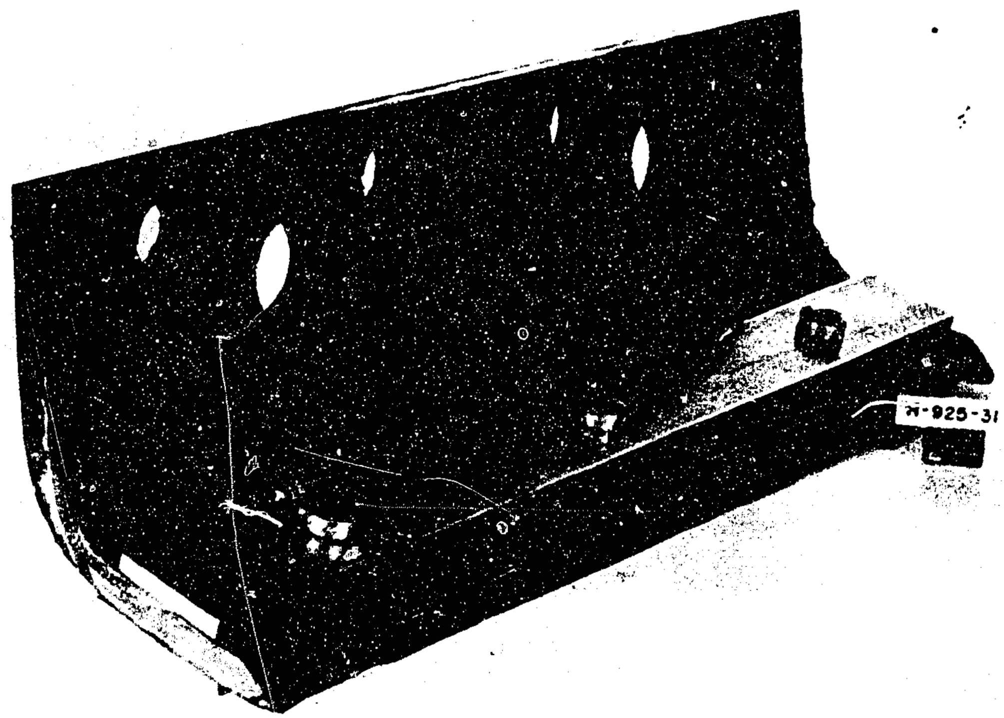
1. The purpose of this sheet is to make a frictional drag comparision of various side seal designs. Therefore, the same assumptions have been made in the frictional drag estimate for each design. The assumptions are:
   (a) Wet coefficient of friction, brass to steel side wall plate, f_B = 0.25.
   (b) Wet coefficient of friction, rubber to steel side wall plate, f_R = 1.25.
   (c) Seal under 40 feet of water head or 17.3 p.s.i.
   (d) Nominal seal to side wall plate gap = zero inches. Initial deflection of molded angular seals C, D, E, F, G, and H assumed zero inches.
2. Sketches of seal are not to scale.

RADIAL GATE SEAL TESTS

COMPUTED FRICTIONAL DRAG COMPARISON OF SIDE SEAL DESIGNS



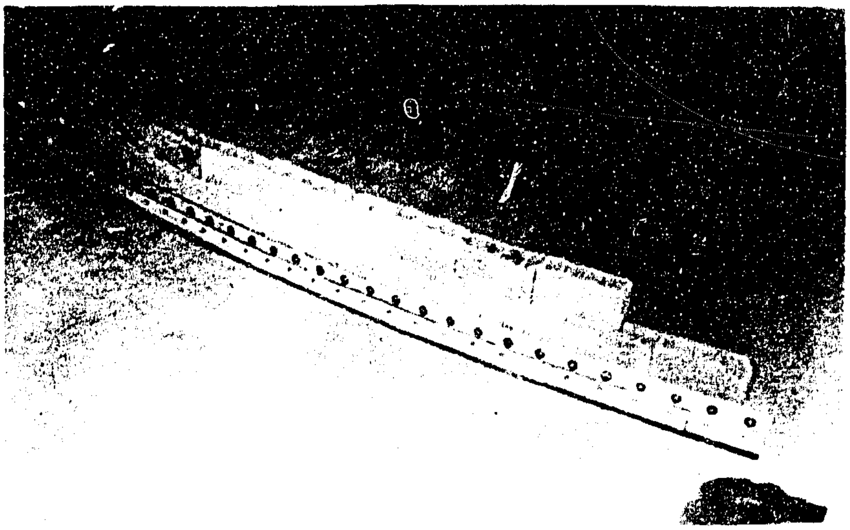
(A) View of the rubber belting seal with brass shoes.



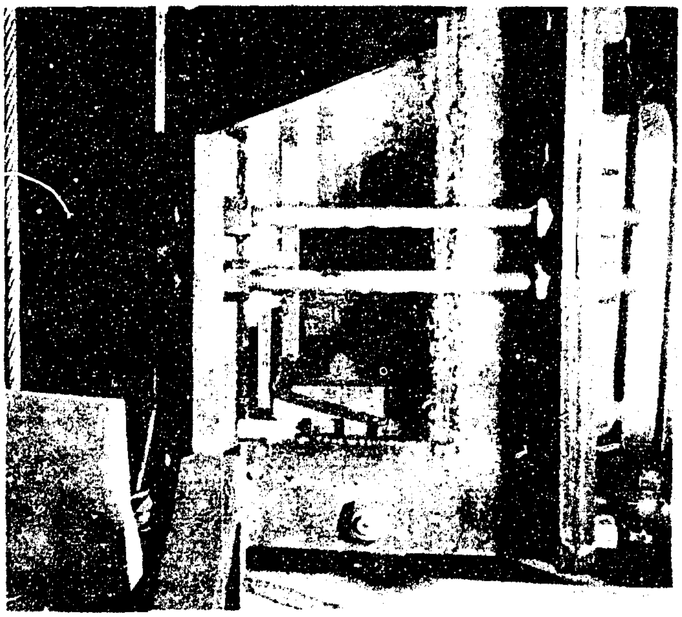
(B) View of the belt type, molded angle seal, with brass shoe, cut from a fabric reinforced angle seal shown on Figure 13A.

RADIAL GATE SEAL TESTS

Belt Type Side Seals with Metal Shoes



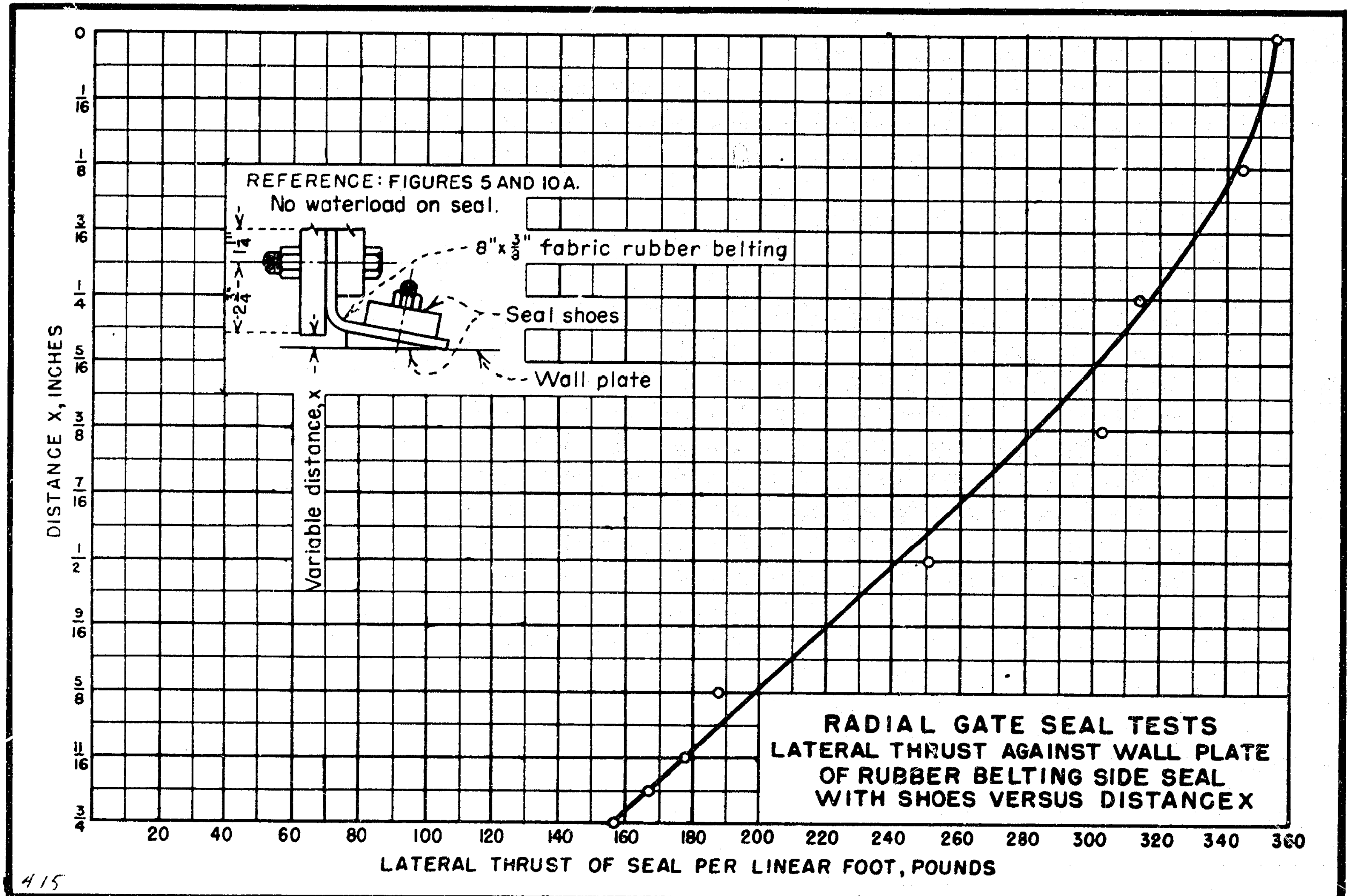
(A) Wooden mock-up of 15 foot length of seal bolted to a 40-foot radius.



(B) View of the seal buckling that occurred after the seal was shifted nearer to the wall plate (painted steel, rig floor) at 50 foot head. The lower brass shoe would not slide upstream.

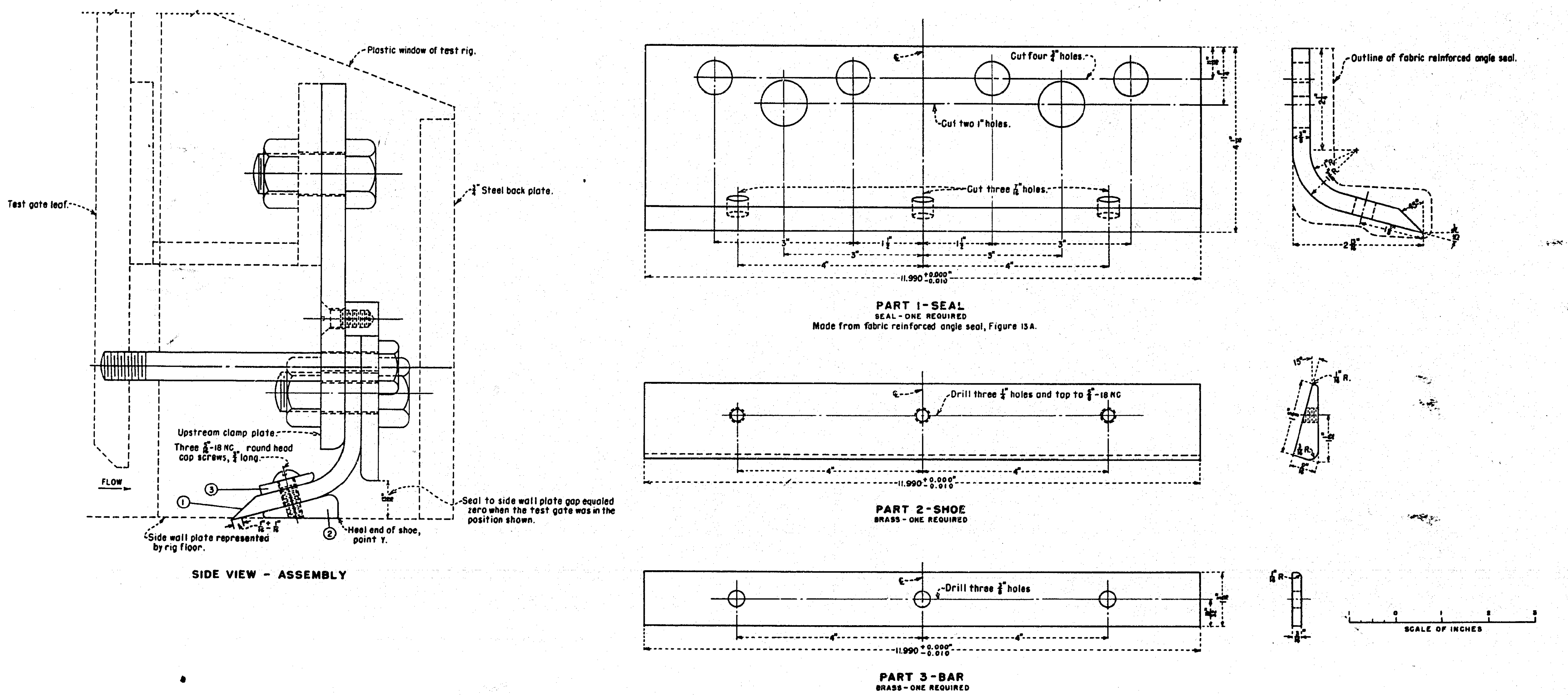
RADIAL GATE SEAL TESTS

Mock-up and Operating View of the 3/8-by 8-inch Rubber Belting Side Seal with Shoes



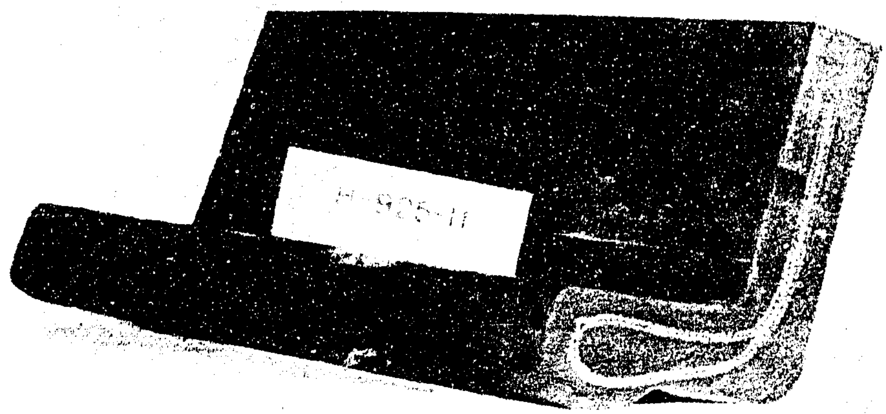
REFERENCE: FIGURES 5 AND 10 A.
No waterload on seal.
8" x 3/8" fabric rubber belting
Seal shoes
Wall plate
Variable distance, x
DISTANCE X, INCHES
0
1/16
1/8
3/16
1/4
5/16
3/8
7/16
1/2
9/16
5/8
11/16
3/4
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
LATERAL THRUST OF SEAL PER LINEAR FOOT, POUNDS
RADIAL GATE SEAL TESTS
LATERAL THRUST AGAINST WALL PLATE
OF RUBBER BELTING SIDE SEAL
WITH SHOES VERSUS DISTANCE X

415

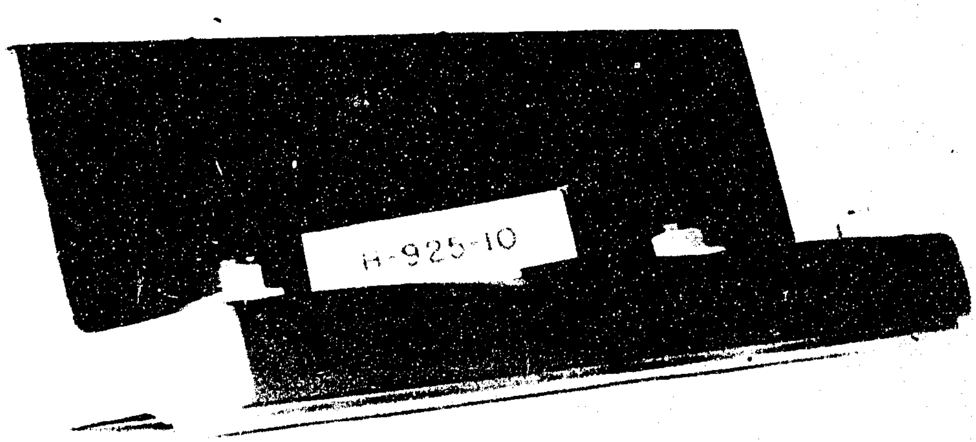


RADIAL GATE SEAL TESTS
MOLDED BELT TYPE SIDE SEAL

415



(A) View of the angle seal with fabric reinforcement.



(B) View of the all-rubber angle seal with a brass bar added to reduce frictional drag on wall plate.

RADIAL GATE SEAL TESTS

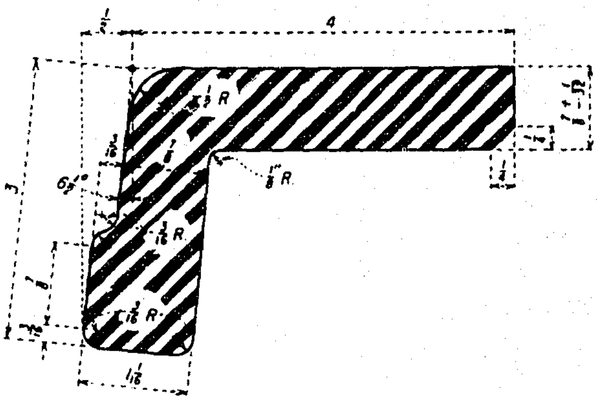
Views of the Molded Angle Side Seal with Fabric Reinforcement and a Brass Bar

LIST OF PARTS FOR THREE GATES

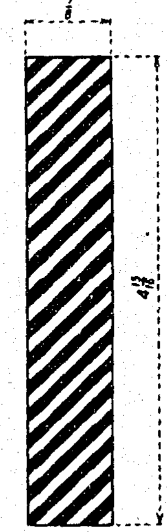
DRAWING NUMBER	PART NO.	NUMBER REQUIRED	DESCRIPTION	MATERIAL CLASSIFICATION	MAT'L. REF. NO.
328-D-1046	1	6 Pc's.-34'-0 lg	Seal	Rubber	M13
328-D-1046	2	3 Pc's.-42'-0 lg.	Seal	Rubber	M20

MATERIALS - SPECIFICATIONS AND MINIMUM PHYSICAL PROPERTIES

MATL REF NO.	MATERIAL	ULTIMATE TENSILE STR #/□	% ELONG IN 2"	REMARKS
M13	Rubber (Natural)	3,000	500	DUROMETER HARDNESS 60 TO 70
M20	Rubber	3,400	675	DUROMETER HARDNESS 40 ± 5



①
SEAL
RUBBER M13
6 REQ'D - MARK 1044-1



②
SEAL
RUBBER M20
3 REQ'D - MARK 1044-2

NOTES

Crate seals to prevent damage in transit.
Seals to be cut to length and drilled in field assembly.

REFERENCE DRAWINGS

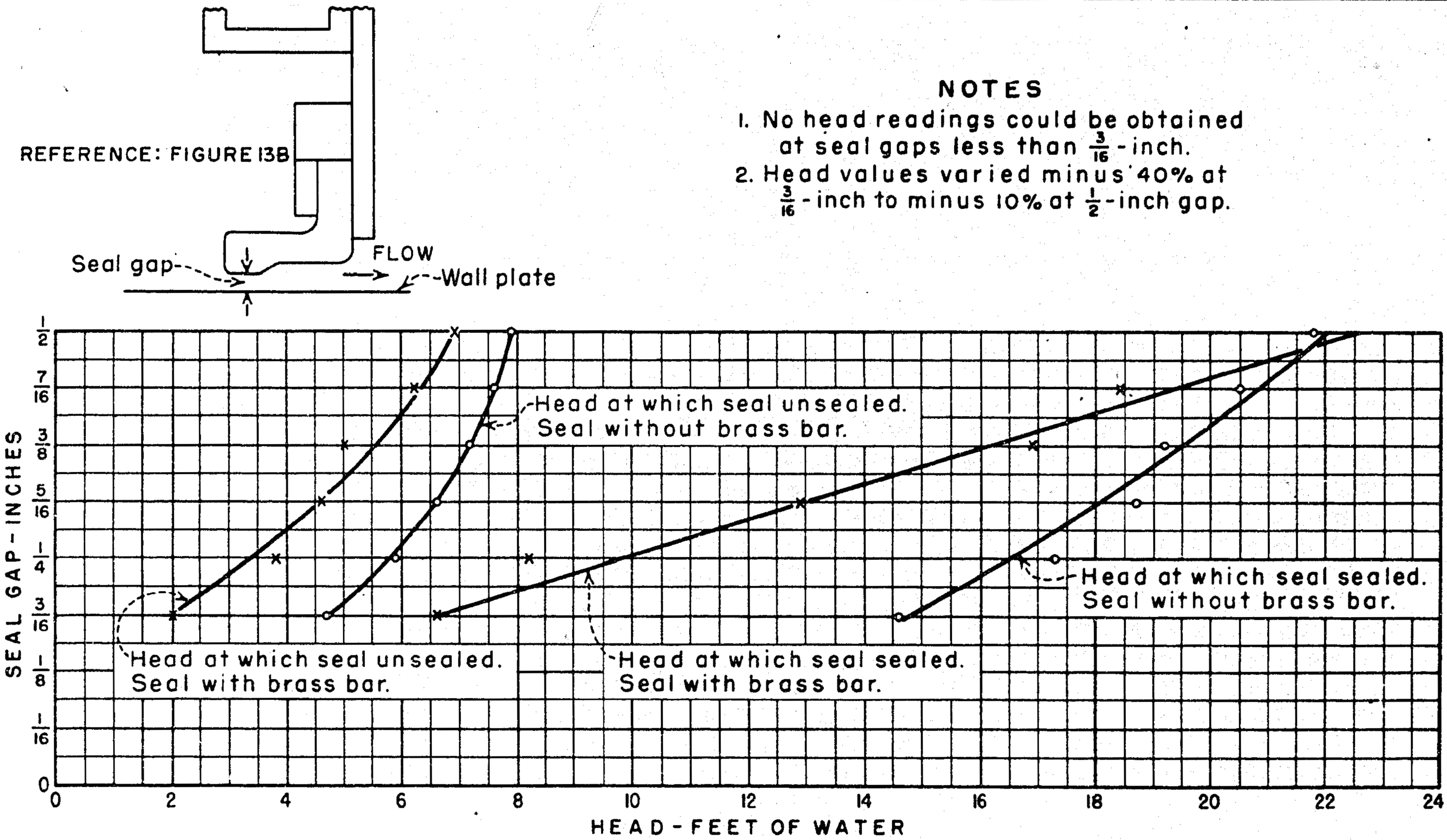
42' x 30' RADIAL GATE
GATE ASSEMBLY 328-D-1025
SIDE AND BOTTOM SEAL
ASSEMBLY 328-D-1044
SECTIONS 328-D-1045

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
FRENCHMAN-CAMBRIDGE DIVISION-NEBR.

TRENTON DAM
SPILLWAY
42' x 30' RADI L GATE
SEALS - LIST OF PARTS - MATERIALS

DRAWN J.W.B. SUBMITTED [signature]
TRACED A.H. RECOMMENDED [signature]
CHECKED JAE APPROVED [signature]
DENVER, COLORADO - NOV. 20, 1950
SHEET 23 OF 23

328-D-1046

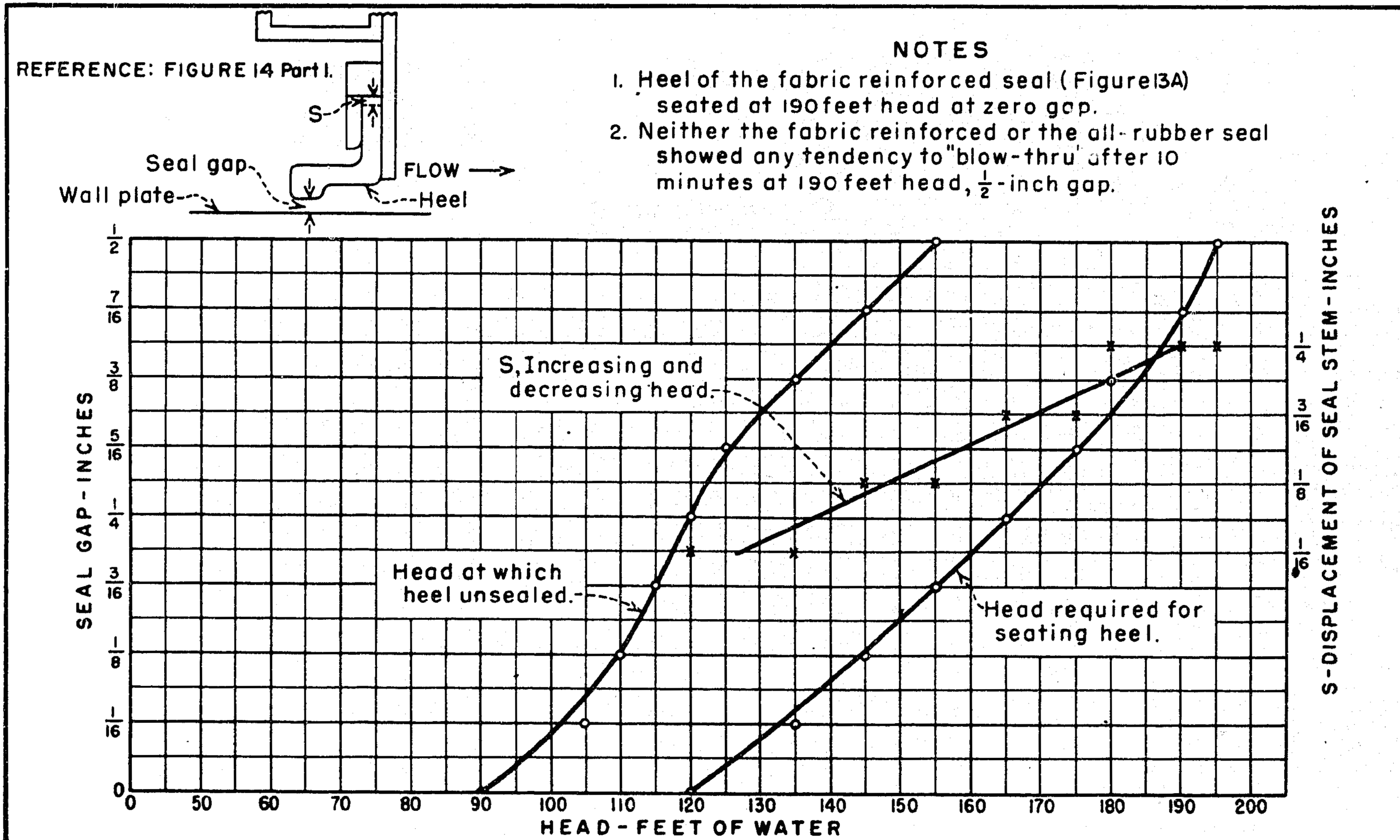


RADIAL GATE SEAL TESTS

SEALING AND UNSEALING HEADS OF THE ALL RUBBER ANGLE SIDE SEAL WITH AND WITHOUT BRASS BAR

415

Report Hyd.323 FIGURE 15

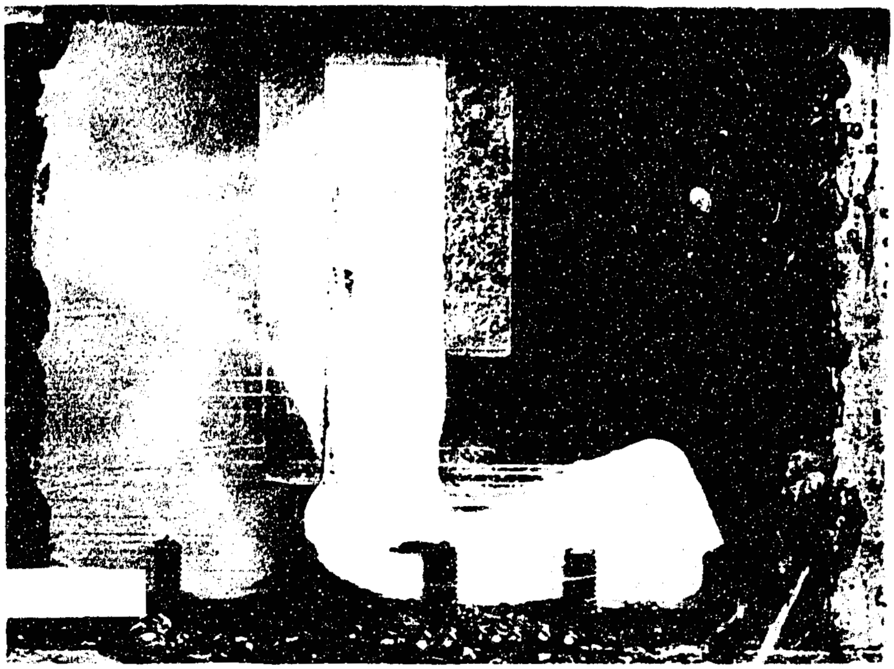


RADIAL GATE SEAL TESTS

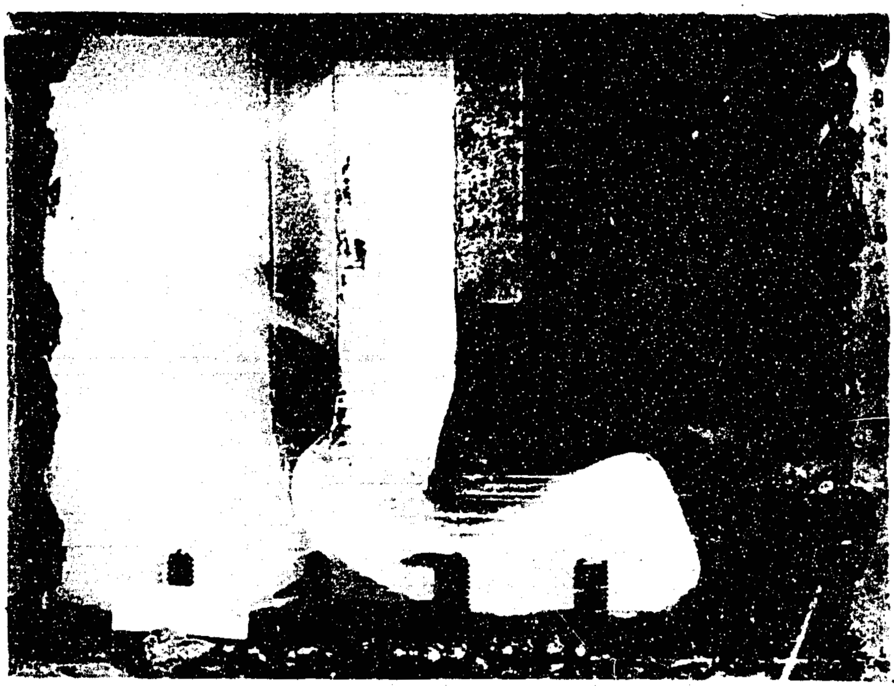
HEAD REQUIRED TO SEAT AND SEAL THE HEEL END OF THE ALL RUBBER ANGLE SIDE SEAL

Report Hyd. 323 FIGURE 16

415



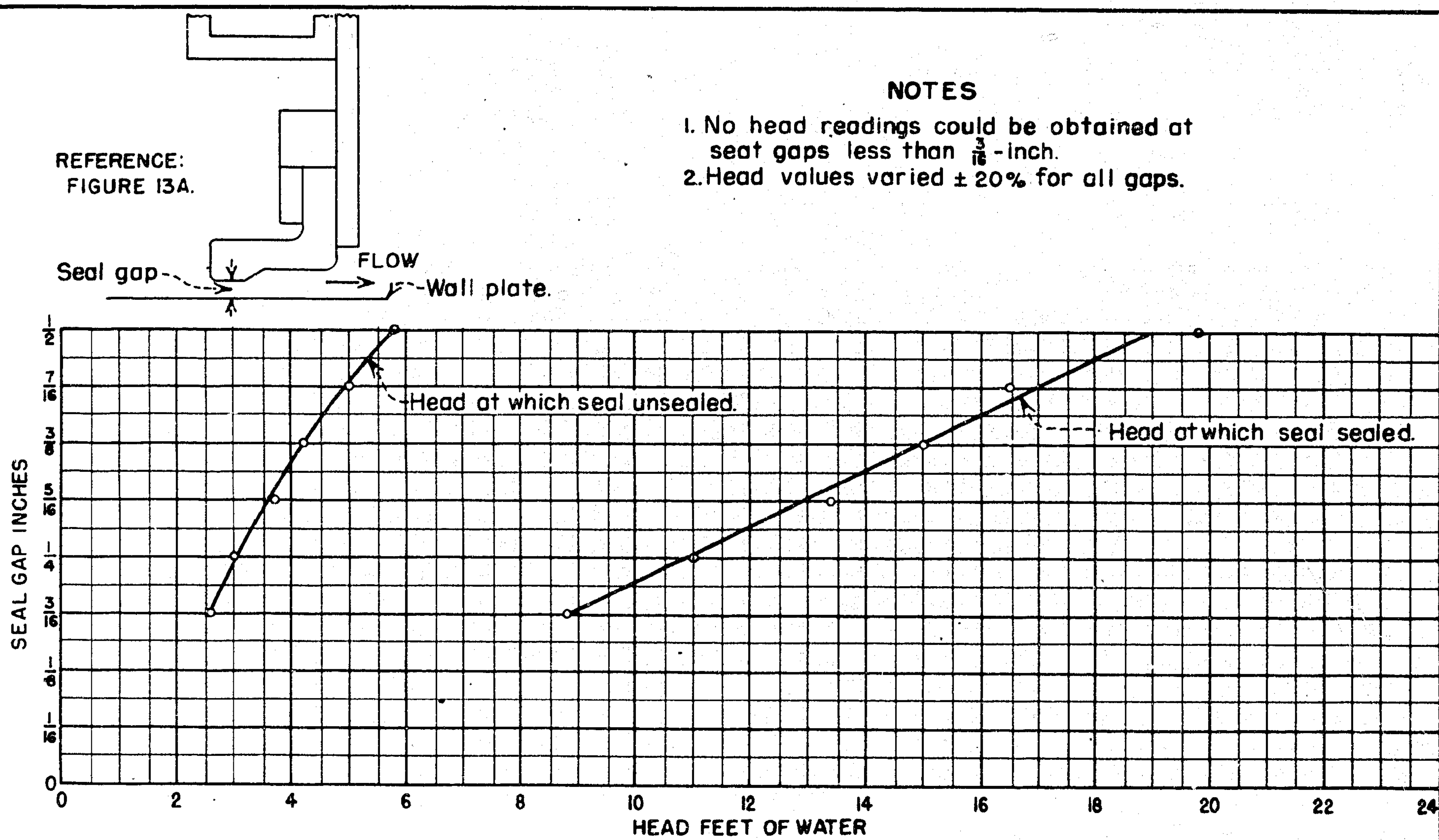
(A) Zero gap. Note the large area of contact of the seal with the wall plate (rig floor) which will increase the frictional drag of the gate. This condition might occur at a much lower head with an aged seal.



(B) One-half inch gap.

RADIAL GATE SEAL TESTS

Views of the All-Rubber Molded Angle Side Seal
Seated at 190 Feet Head.

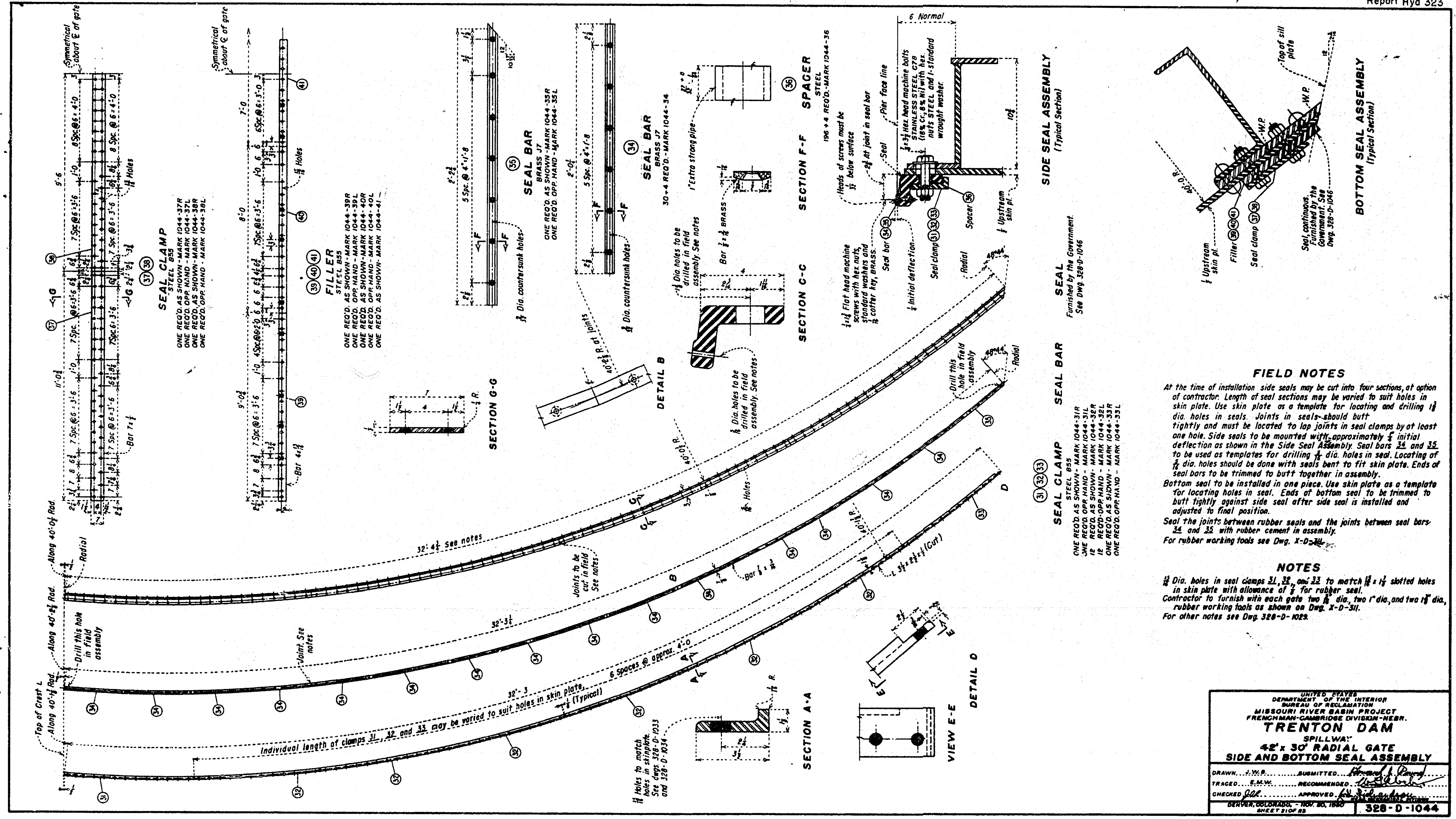


RADIAL GATE SEAL TESTS

SEALING AND UNSEALING HEADS OF THE FABRIC REINFORCED ANGLE SIDE SEAL

Report Hyd. 323 FIGURE 18

415



FIELD NOTES

At the time of installation side seals may be cut into four sections, at option of contractor. Length of seal sections may be varied to suit holes in skin plate. Use skin plate as a template for locating and drilling 1⅛ dia. holes in seals. Joints in seals should butt tightly and must be located to lap joints in seal clamps by at least one hole. Side seals to be mounted with approximately ¼ initial deflection as shown in the Side Seal Assembly. Seal bars 34 and 35 to be used as templates for drilling 5/16 dia. holes in seal. Locating of 5/16 dia. holes should be done with seals bent to fit skin plate. Ends of seal bars to be trimmed to butt together in assembly.

Bottom seal to be installed in one piece. Use skin plate as a template for locating holes in seal. Ends of bottom seal to be trimmed to butt tightly against side seal after side seal is installed and adjusted to final position.

Seal the joints between rubber seals and the joints between seal bars 34 and 35 with rubber cement in assembly.

For rubber working tools see Dwg. X-D-311.

NOTES

13/16 Dia. holes in seal clamps 31, 32, and 33 to match 13/16 x 1½ slotted holes in skin plate with allowance of ⅞ for rubber seal.

Contractor to furnish with each gate two ⅝" dia., two 1" dia., and two 1⅛" dia., rubber working tools as shown on Dwg. X-D-311.

For other notes see Dwg. 328-D-1029.

UNITED STATES
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FRENCHMAN-CAMBRIDGE DIVISION-NEBR.

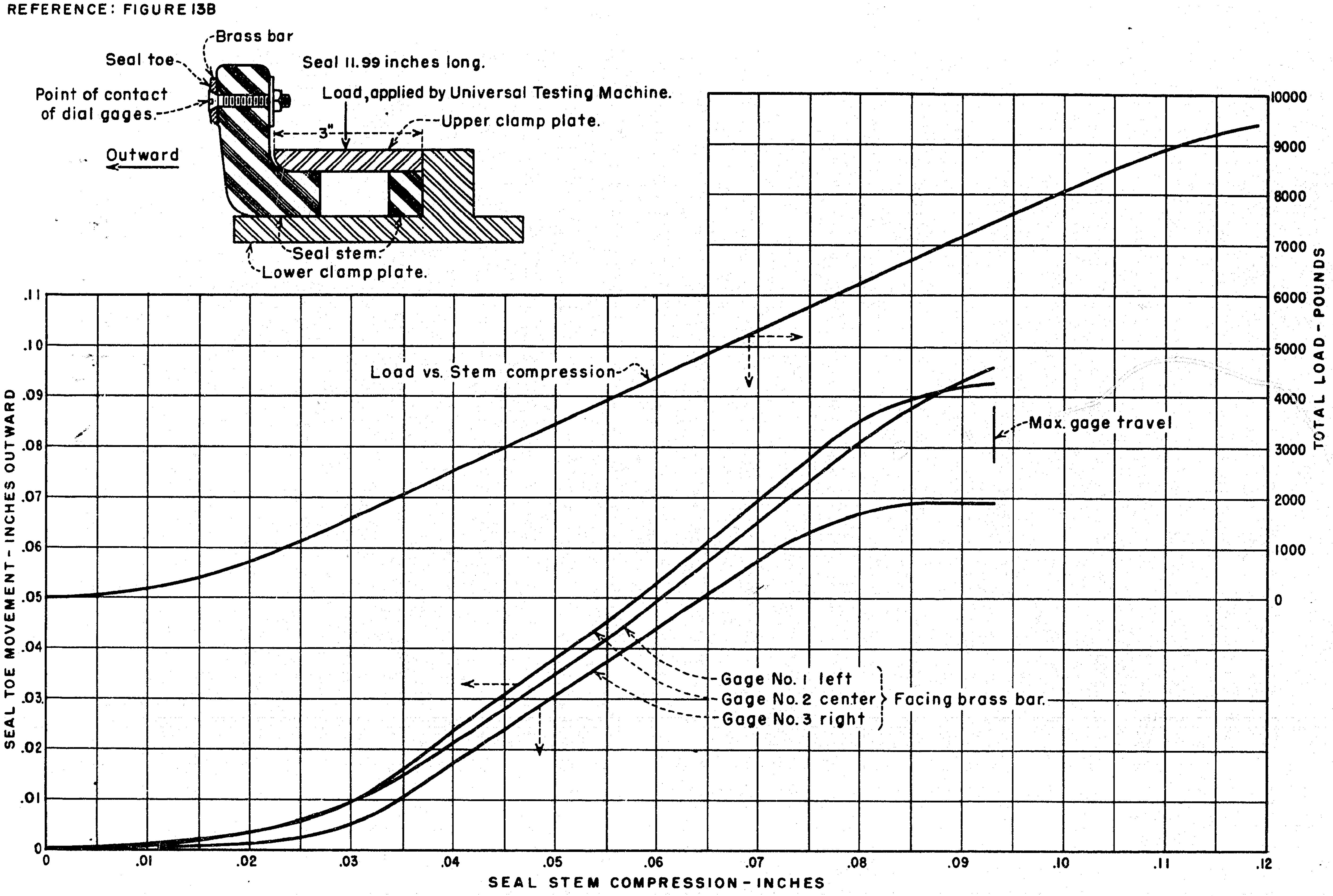
TRENTON DAM

SPILLWAY
42' x 30' RADIAL GATE
SIDE AND BOTTOM SEAL ASSEMBLY

DRAWN J.W.B. SUBMITTED
TRACED E.M.W. RECOMMENDED
CHECKED J.A.E. APPROVED

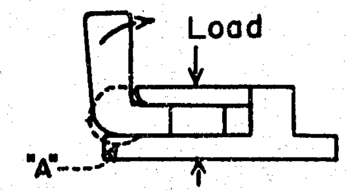
DENVER, COLORADO, - NOV. 20, 1950
SHEET 21 OF 23

328-D-1044

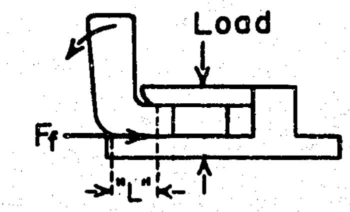


NOTES

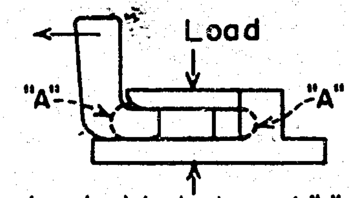
Seal toe moved outward. There seems to be three components to the toe movement.

1. 

Since bulge at "A" cannot form, toe tended to turn ↗.

2. 

Since there was a restraining frictional force F_f acting over length "L" of lower clamp plate and none above on upper clamp plate, toe tended to turn ↙.

3. 

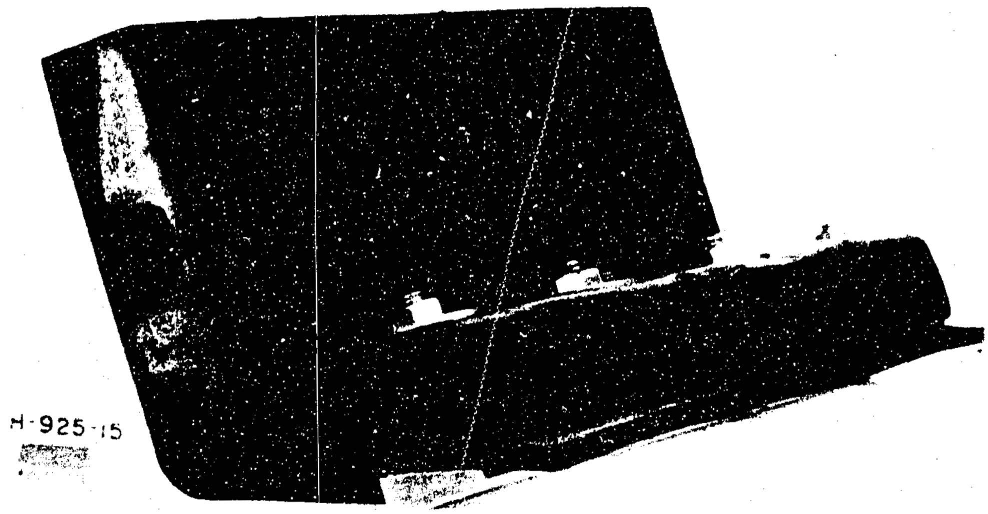
Stem tended to bulge at "A". Left side was free to move, pushing toe to left; right side was not free to bulge, pushing toe further to left. This component probably was a major one.

4. The seal toe movement was based upon approximately a one foot length of seal clamped flat, and does not consider the effect of the seal clamped to a large radius (40 feet, Figure 2).

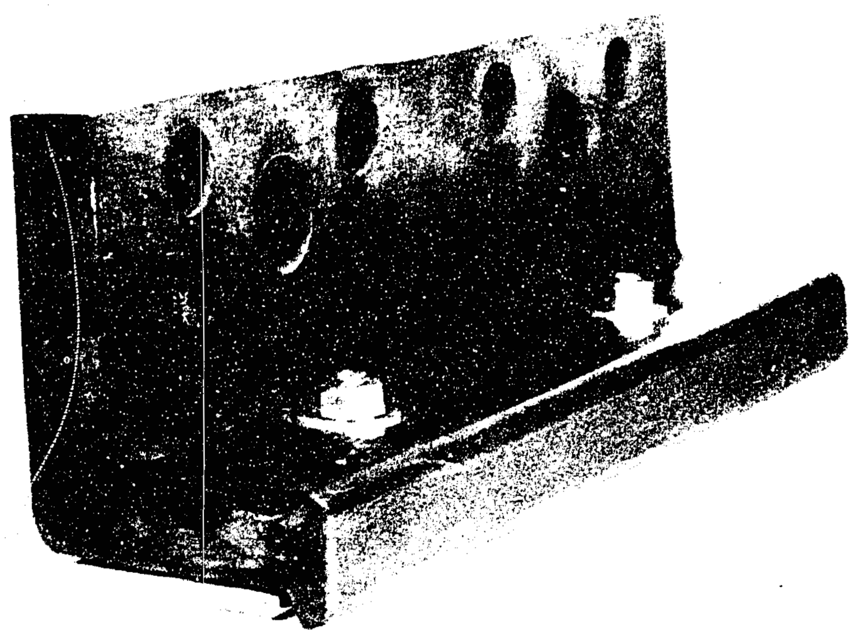
RADIAL GATE SEAL TESTS

MOVEMENT OF SEAL TOE OF THE ANGLE SIDE SEAL DUE TO COMPRESSION OF SEAL STEM

415



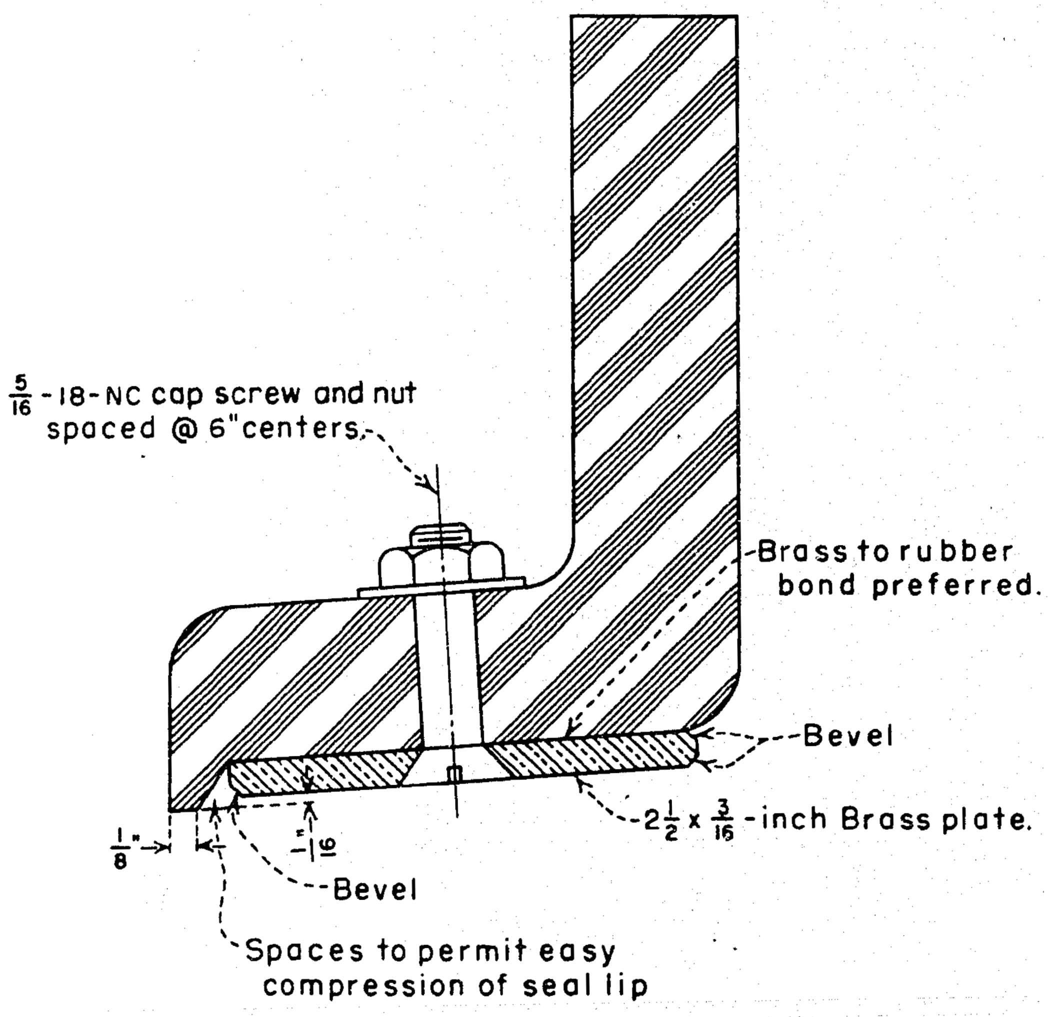
(A) View of the angle seal with a brass bar plus a rubber sealing flap.



(B) View of the angle seal with rubber removed from the lower leg and a brass plate added.

RADIAL GATE SEAL TESTS

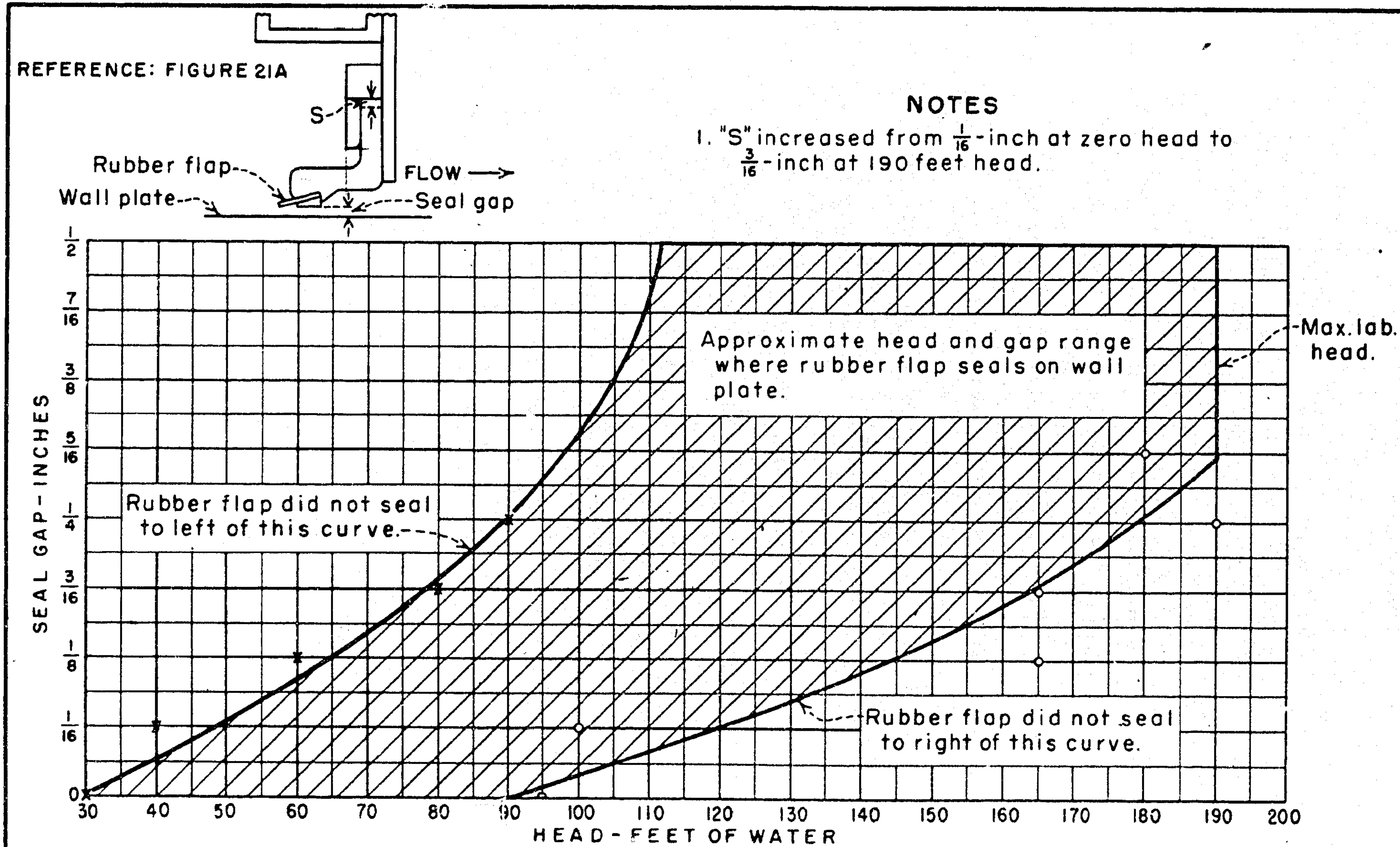
Views of the Angle Side Seal with a Brass Bar plus a Rubber Sealing Flap and with a Brass Plate.



RADIAL GATE SEAL TESTS

ANGLE SIDE SEAL
WITH BRASS PLATE ADDED

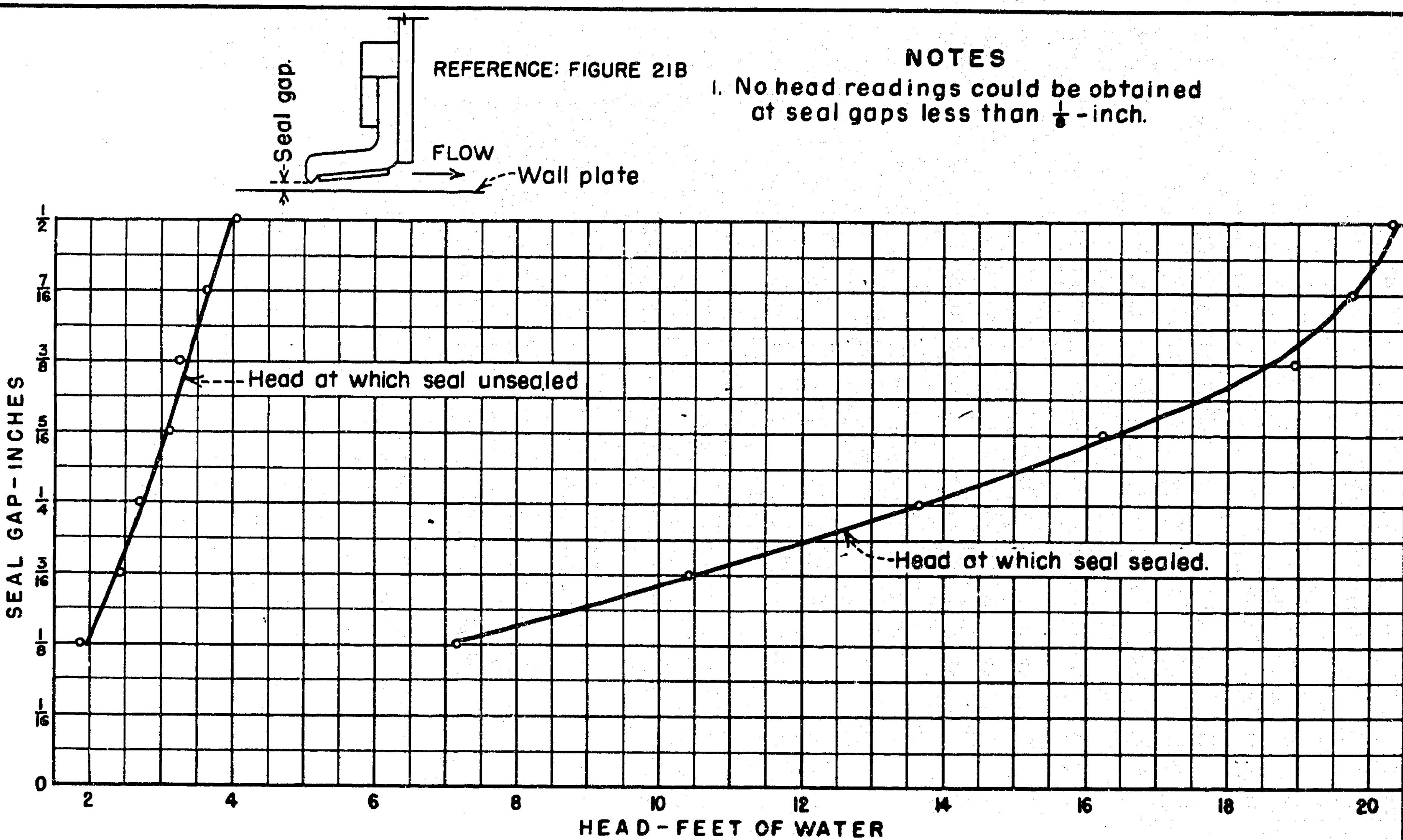
415



RADIAL GATE SEAL TESTS

HEAD LIMITATIONS TO OBTAIN A SEAL OF THE ANGLE SIDE SEAL WITH BRASS BAR AND RUBBER FLAP ADDED

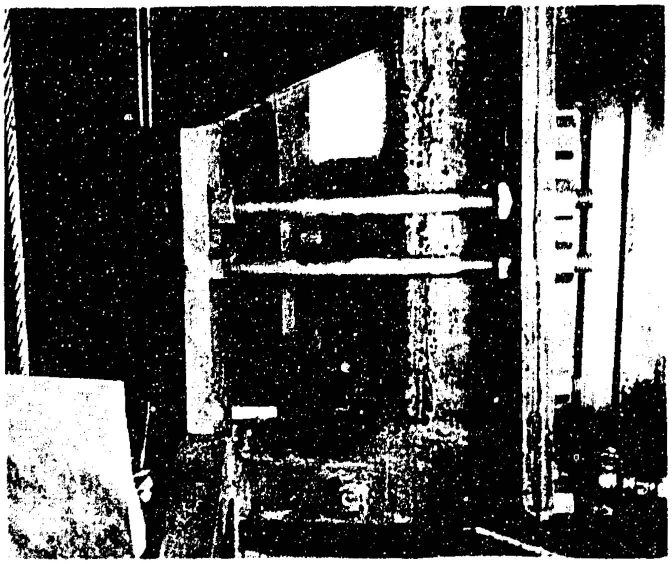
415



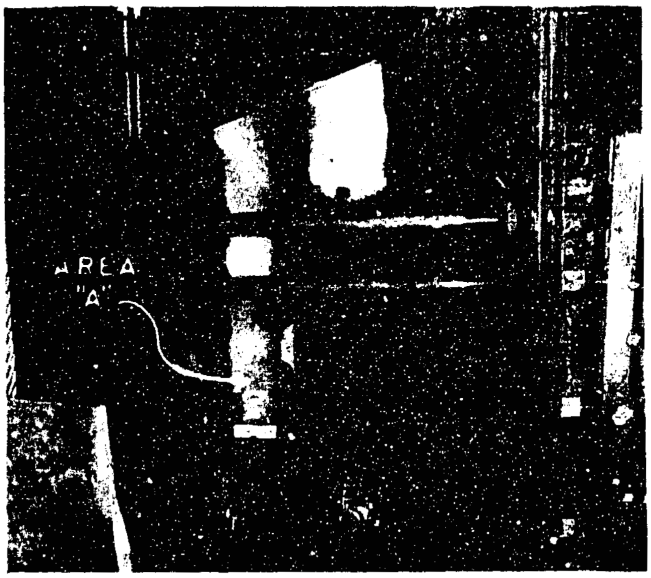
RADIAL GATE SEAL TESTS

SEALING AND UNSEALING HEADS OF THE ALL RUBBER ANGLE SIDE SEAL WITH BRASS PLATE ADDED

4135



(A) Sealing position at 40 feet head. The seal water load was carried to the wall plate (rig floor) by the upstream end of the brass plate and by the rubber sealing lip of the seal.



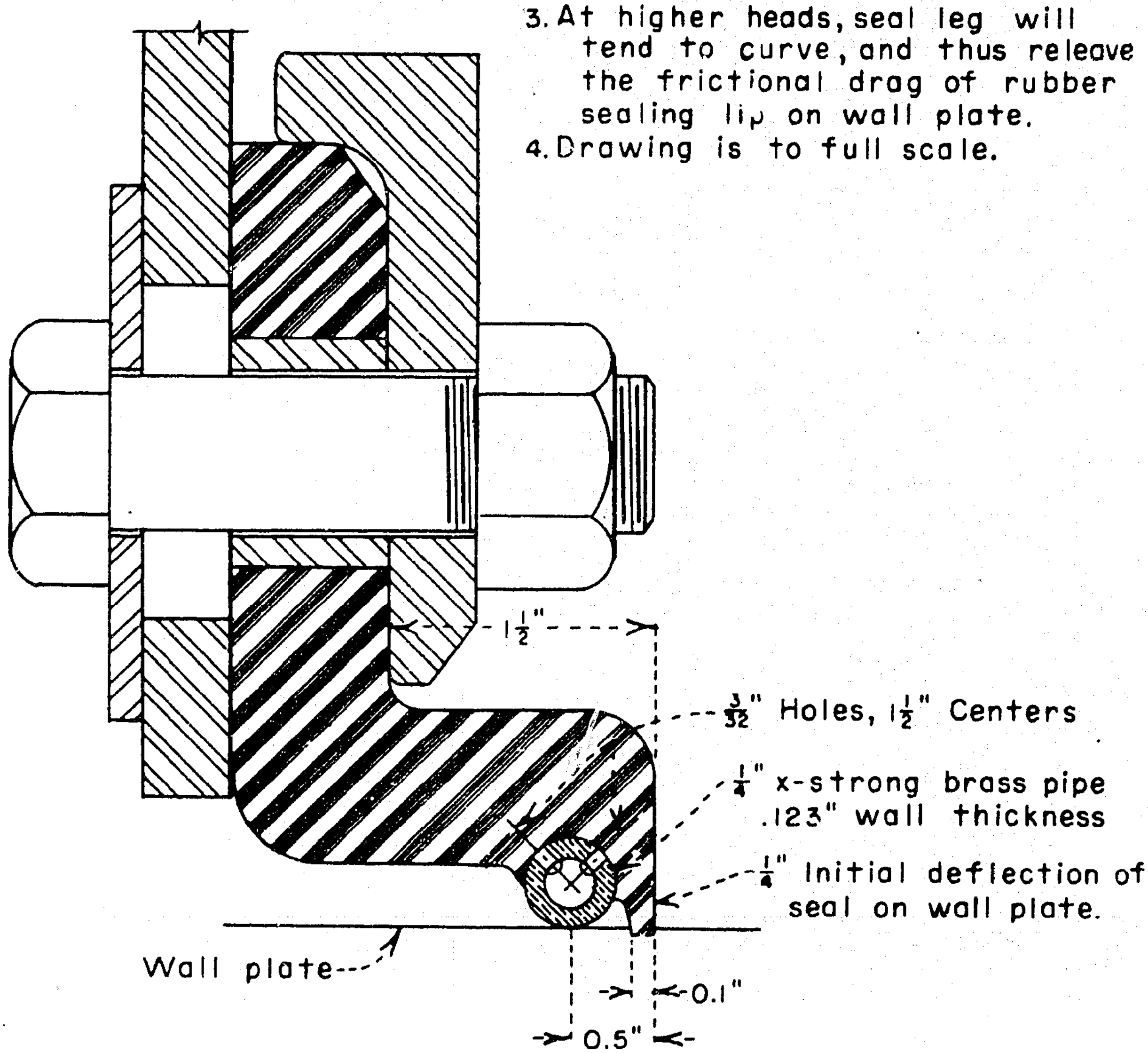
(B) Sealing position at 190 feet head. Non-representative of field pressures due to flow restriction at area A--tended to separate brass plate from seal. Brass plate became horizontal at 100 feet head.

RADIAL GATE SEAL TESTS

Operating Views of the Angle Side Seal with a Brass Plate at 1/2-inch Seal Gap.

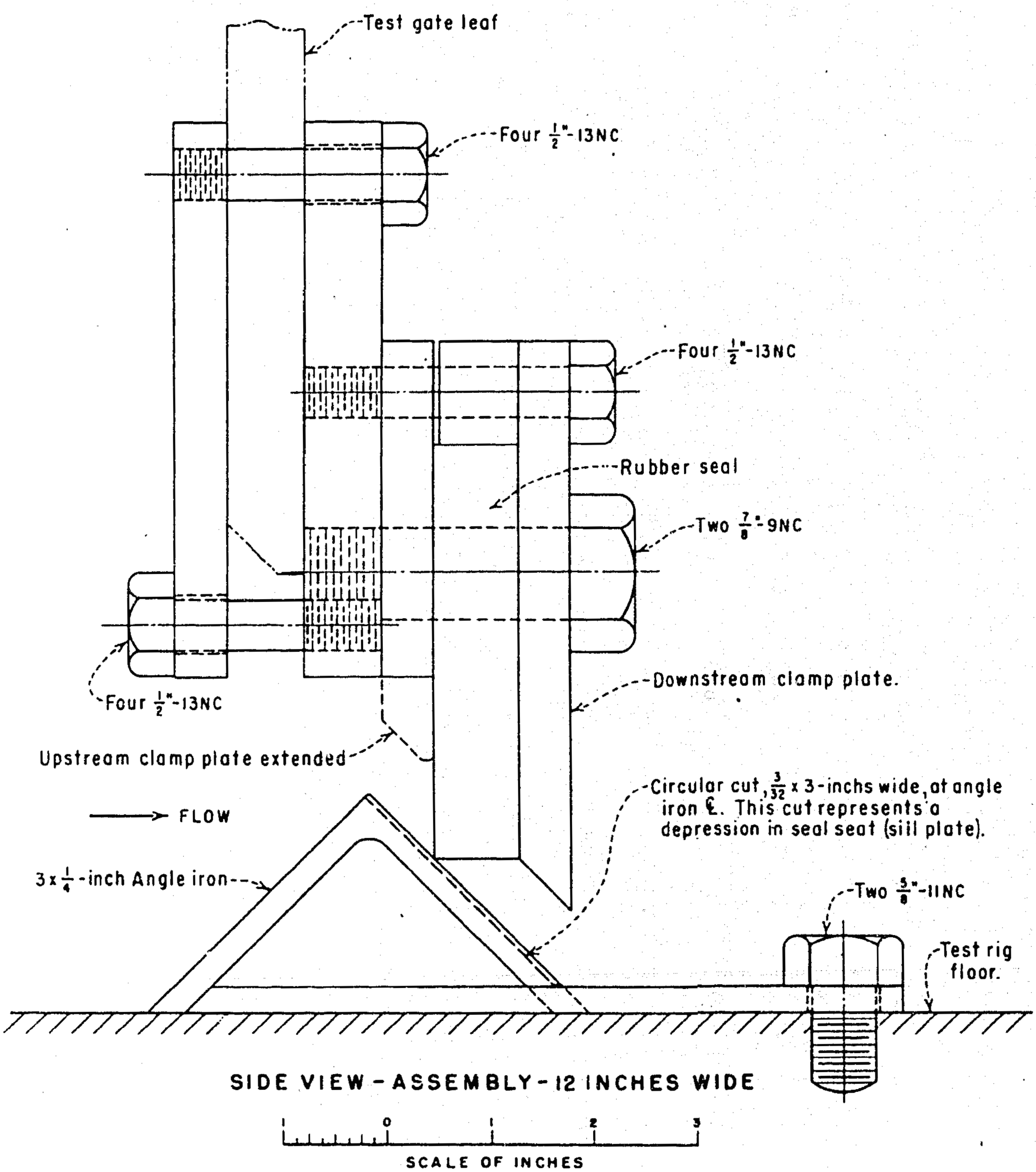
NOTES

1. Approximately one-third of seal water load across the $1\frac{1}{2}$" dimension is carried by the gate; the remainder of water load is carried to the wall plate.
2. Brass pipe may be slightly curved during assembly to fit gate curvature.
3. At higher heads, seal leg will tend to curve, and thus releave the frictional drag of rubber sealing lip on wall plate.
4. Drawing is to full scale.



RADIAL GATE SEAL TESTS

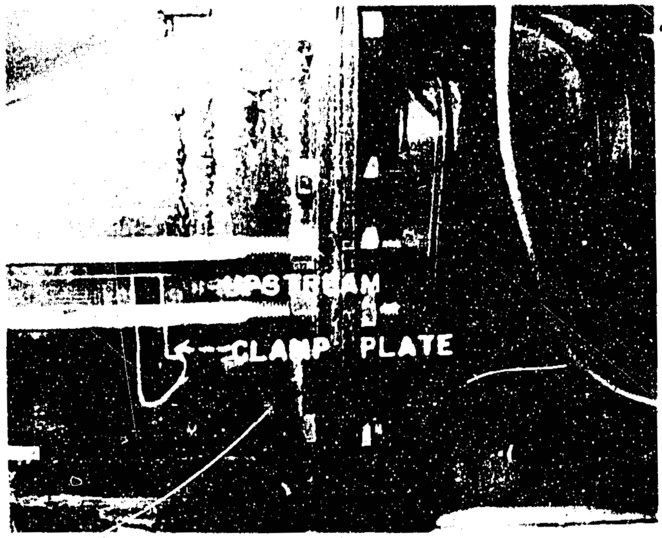
PROPOSED SIDE SEAL WITH A BRASS PIPE AND A RUBBER SEALING LIP



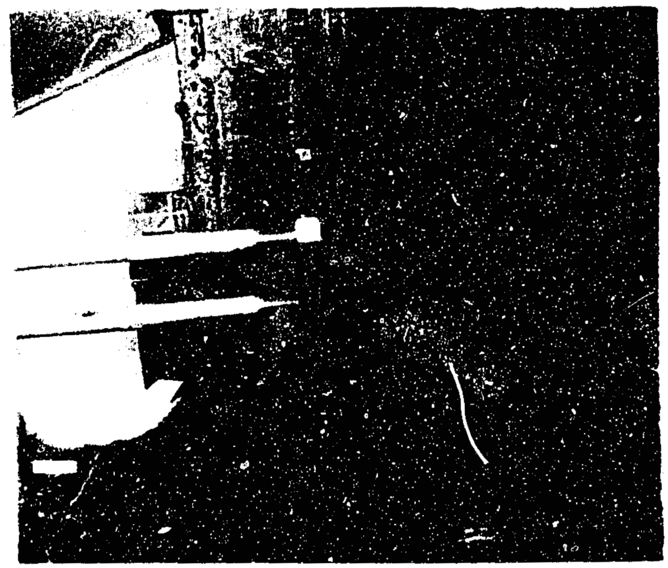
RADIAL GATE SEAL TESTS

ARRANGEMENT FOR HYDRAULIC TESTS OF BOTTOM SEAL

415



(A) Seal compressed 100 percent at 40 feet head. The seal was deformed upstream under the upstream clamp plate. The seal is outlined in white line.

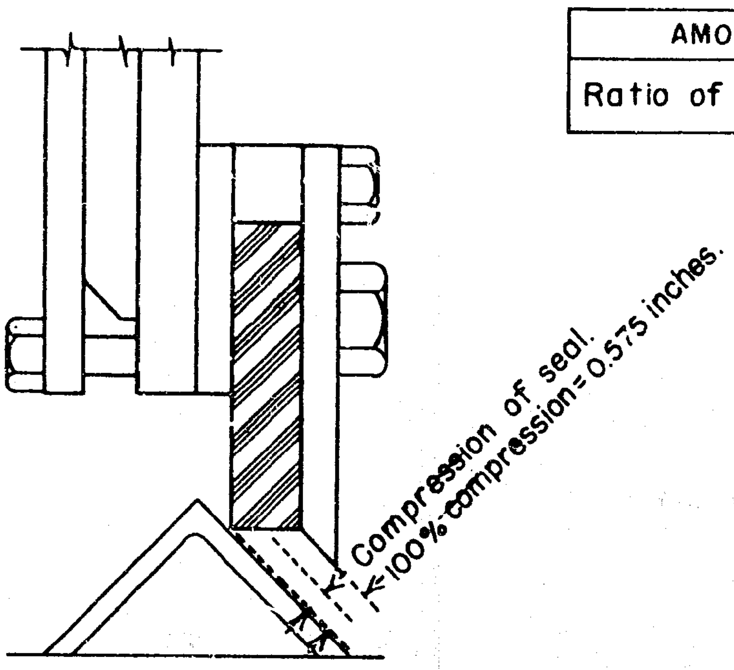


(B) 3/4-inch gap, 190 feet head. The seal is deformed slightly under the downstream clamp plate.

RADIAL GATE SEAL TESTS

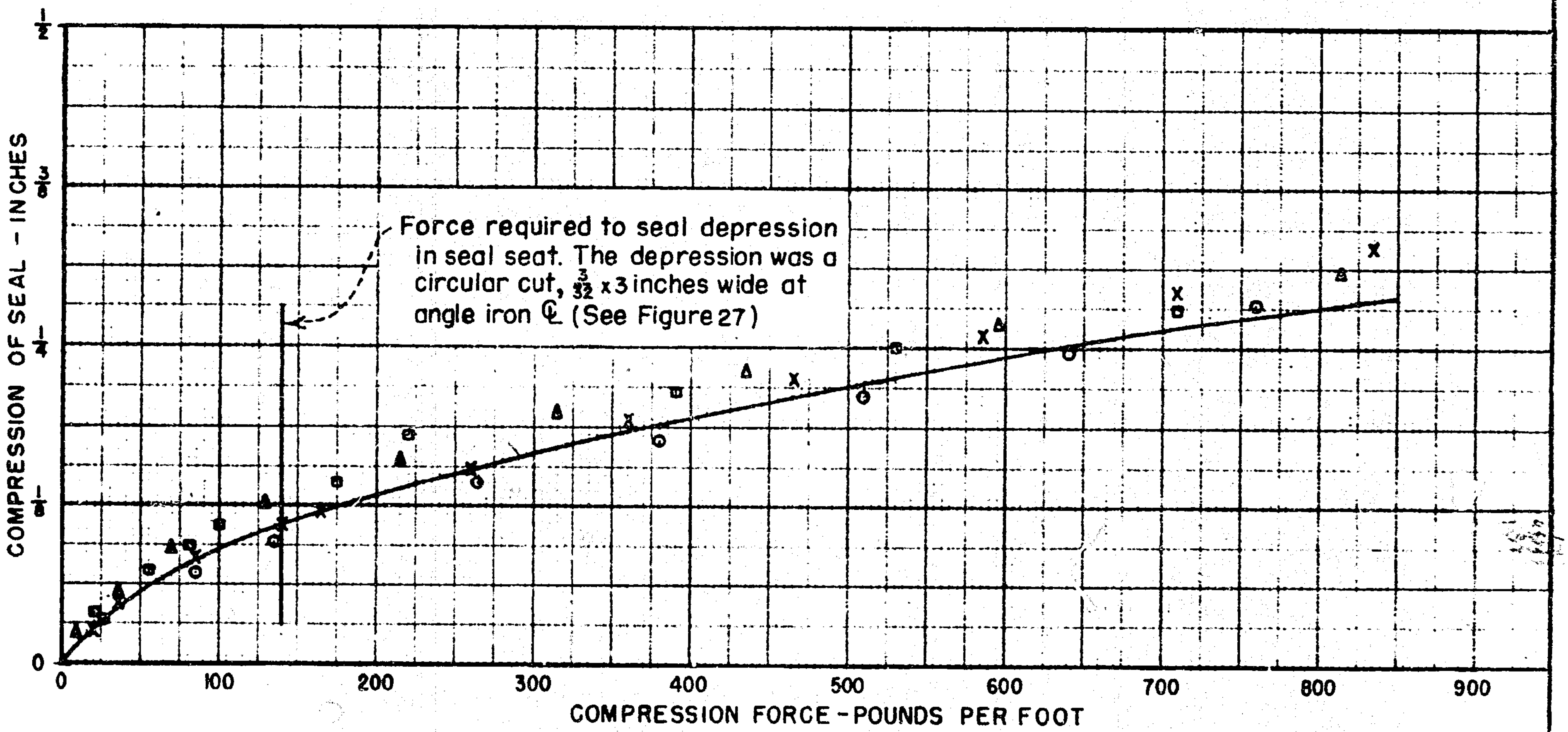
Operating Views of the Soft Rubber, Type A Shore Durometer 38, Gate Bottom Seal

AMOUNT OF SEAL COMPRESSION - INCHES =	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
Ratio of $\frac{\text{Force required to compress 69 duro. seal}}{\text{Force required to compress 38 duro. seal}}$ =	1.60	1.67	2.04	2.33	2.56

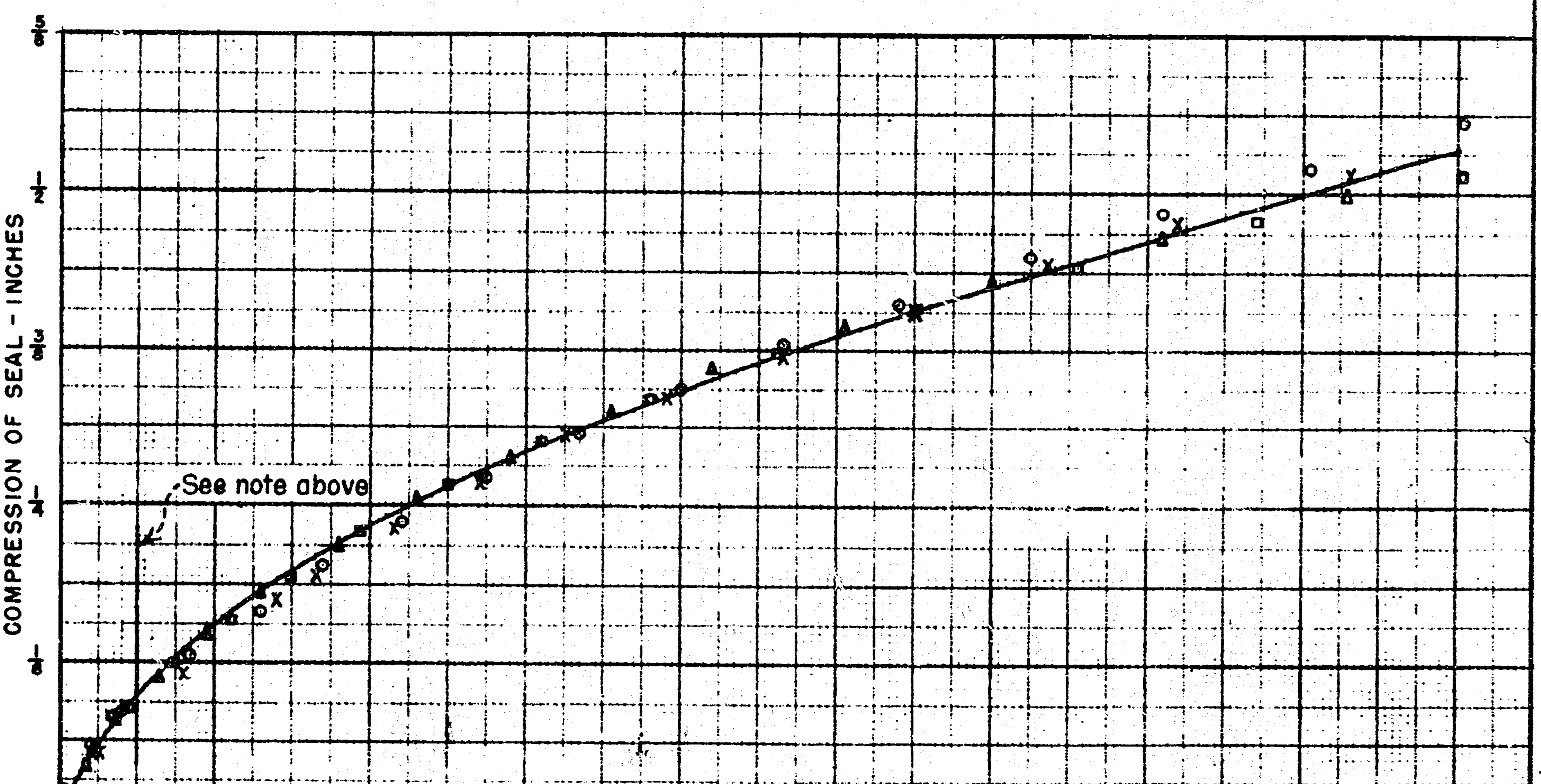


NOTES

1. WET SEAL SEAT
   - x Increasing Force
   - Δ Decreasing Force
2. DRY SEAL SEAT
   - o Increasing Force
   - □ Decreasing Force
3. Data obtained from Universal Testing Machine.



A. HARD RUBBER-69 DUROMETER TYPE A SHORE



B. SOFT RUBBER-38 DUROMETER TYPE A SHORE

RADIAL GATE SEAL TESTS

FORCE REQUIRED TO COMPRESS RADIAL GATE BOTTOM SEAL