UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
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Laboratory Report No. 187
Hydraulic Laboratory

By: J. W. Ball

Subject: Test operation of 84-inch Needle Valve By-pass Outlet in Bay R-9 of Right Powerhouse—Grand Coulee Dam—Columbia Basin Project

1. Test operations were conducted on the 84-inch needle valve outlet in bay R-9 of the right powerhouse at Grand Coulee Dam during the summer months of 1945 in accordance with suggestions contained in paragraph 5 of a letter from the Chief Electrical and Mechanical Engineer to Supervising Engineer, Coulee Dam, Washington, dated May 19, 1945.

The relevant portion of the above letter is as follows:

"In order that the maintenance requirements may be more definitely determined, it is suggested that test operations of one of the needle valves be conducted on the project at an early date. Laboratory tests indicate that the needle valves may be operated with high tail water during the periods of high river flow. Test of sufficient duration at the fully-opened position and inspection should be performed to determine the necessary intervals for valve inspection, valve repairs, and cleaning of the paradox control. During the tests the complete installation also should be examined to determine the necessity for revisions. Inasmuch as Engineer James W. Ball is familiar with the laboratory tests conducted by this office, he should observe the project tests."

2. Two reports were prepared concerning the test operations; the first as a letter from the Supervising Engineer to the Chief Engineer, concerning tests conducted on May 25, and June 5, 1945, submitted on June 26, 1945; and the second, a memorandum for the Construction Engineer concerning tests performed on August 7, 8, and 9, 1945, submitted, August 27, 1945. Copies of the reports are contained herein.

June 26, 1945

From: Supervising Engineer

To: Chief Engineer

Subject: Test operation of 84-inch needle valve bypass outlets in right powerhouse--Columbia Basin Project

1. Test operations are being conducted on the 84-inch needle valve outlet in bay R-9 of the right powerhouse in accordance with paragraph 5 of a letter from the Chief Electrical and Mechanical Engineer, dated May 19, 1945, concerning the requirement of coaster gates for the penstocks leading to the valves. Operations thus far indicate that it will be necessary to improve flow conditions in the transition elbow and in the concrete section immediately below before satisfactory operation for extended periods can be expected. The results of the tests made to date and the corrective measures indicated are presented, therefore, in the following paragraphs.

2. The penstock and draft tube of the R-9 outlet unit were filled and the needle valve operated for the initial test about 10:10 a.m., Friday, May 25. The test consisted of four operations. In the first, the coaster gate over the entrance of the penstock was raised four feet above the normal sealing position and the needle retracted slowly to 10 percent opening when the pressure at the lower piezometer section of the penstock, about 100 feet upstream, decreased 20 p.s.i. from that of 148 p.s.i. for the shut off condition. It was considered inadvisable to reduce the pressure further, so the valve was allowed to remain at this opening for a few minutes, and then closed completely. The procedure was the same for the second and third operations, but the coaster gate openings were six and ten feet respectively, and the maximum needle valve openings 25 and 50 percent. The reduction in pressure at the piezometer was 16 and 8 p.s.i. respectively. In the fourth and final operation of the day, the coaster gate was raised completely and the needle retracted slowly to the fully open position where it remained during a period of 15 minutes with the outlet discharging full capacity and while the coaster gate was being lowered and sealed. Operation with the coaster gate at the small openings was for the purpose of increasing the velocities under the gate at the invert of the penstock entrance to dislodge debris from this region, thereby improving conditions for lowering and sealing the gate during future operations. Closing the gate with the

needle retracted completely was for the purpose of testing its action should one of the valves become inoperable at full opening and emergency closure be necessary. The relative intensities of vibration and audible disturbances were observed from the top of the valve, the top of the concrete anchor block encasing the transition elbow, and the floor of the elevation 921 gallery over the draft tube. The river flow below the dam for the initial test was 198,000 c.f.s. with a tailwater elevation at the Highway bridge of 959.1.

3. As the valve was opened for the first time in the initial test, sounds, seeming to originate from objects in the valve flow striking the transition elbow, were audible from the top of the concrete anchor block in which the elbow is embedded. The objects were believed to be rock and pieces of metal flushed from an accumulation of debris in the base of the trashrack by the high-velocity stream passing into the penstock when the coaster gate was near the closed position. A distant crackling sound of low intensity, seeming to originate near the downstream end of the valve, was noted during the opening and closing cycles and for the short period the valve was operated at the 10 percent opening. It was necessary during the opening cycle of the operation to retract the needle about 5 percent to attain sufficient momentum in the valve jet to force the tailwater from the transition elbow, to drain the air vent and aerate the valve jet. There was a slight vibration of the vent system which increased noticeably as the above action occurred and then seemed to return to its original intensity to remain constant for the operating cycle above this point. Water spouted from the inlet of the vent pipe as the valve was closed. Apparently air trapped in the dome of the concrete anchor encasing the transition elbow as the flow decreased moved up through the elbow into the air manifold and out through the 18-inch vent pipe causing water to spout several feet above the vent inlet. This action took place two or three times immediately after the valve had been closed. The reason was not apparent immediately, but a satisfactory explanation was discovered during subsequent operations.

4. For the second operation in which the coaster gate was raised six feet and the needle retracted to a maximum opening of 25 percent, the action was similar to that described in paragraph 3 for the 10 percent opening. However, the sound of flowing water, the crackling and the vibration of the concrete anchor block were intensified. The change was more pronounced in the vibration than in the other factors. The same spouting action occurred at the vent inlet as in the previous operation.

5. The roar of flowing water increased as the valve was opened to 50 percent in the third case. The steady crackling noted near the downstream end of the valve in the two previous operations was still in evidence but seemed to be of lower intensity. The opening might have been less critical for creating pressure conditions inducing cavitation on the nozzle and needle of the valve. However, this may not have been the case since the roar of flowing water was louder and may have produced a dampening effect. In addition, there were sharp reports resembling the crack of a rifle fired in the distance. Vibration of the concrete anchor and

vent pipe seemed increased over that for the smaller openings. The spouting action at the end of this operation was unchanged.

6. As the opening increased beyond 50 percent when the valve was operated for the fourth time, the vibration of the entire system increased and loud, intermittent popping reports began to occur. It was impossible to detect whether these reports originated at the exit of the valve, in the transition elbow, or in the draft tube below, but intense vibrations, feeling like sharp blows from a small hammer to the soles of the shoes, were experienced from the top of the concrete block encasing the elbow. Vibrations in the floor of the elevation 921 gallery over the draft tube seemed of about the same intensity. There was no perceptable change in any of these conditions during the 15 minute period with the needle valve wide open. As the coaster gate was lowered to close the penstock entrance, large variations in pressure were recorded by the gage connected to the lower penstock piezometer ring about 100 feet upstream from the valve; otherwise no adverse conditions were noted. The outlet was unwatered during the afternoon and preparations made to inspect it on the following day.

7. From the conditions observed during operation of the outlet for the initial test, it was concluded that cavitation was occurring in the system at or beyond the downstream end of the valve. This conclusion was corroborated when an inspection was made the following day.

8. Though the spouting of water from the entrance of the air vent as the valve is closed was not considered serious, some corrective measure seemed desirable. It was believed that the action could be minimized or elimated by operating the needle very slowly as the valve closes beyond the 5 percent opening. This proved to be the case when the valve was operated carefully during the closing cycle of a test made on June 5, and the spouting action did not take place. Some corrective measure may be necessary however, since closure at the slow speed required may not be possible with the motor operated control.

9. The vibrations from the operation of the outlet were recorded at the seismograph station located a short distance upstream from the dam on the left shore of Roosevelt Lake. No disturbance in addition to that caused by the spillway could be detected on the seismogram for the first two operations of the valve, and only slight deflection was noted for the third when the valve was at the 50 percent opening for a short period. However, the amplitude of that for the spillway and outlet combined during the operation of the outlet at full capacity appeared to be 4 to 6 times that of the spillway under the current flow conditions with 198,000 c.f.s. passing the dam, and was considered to be more intense than with the river outlets operating. The frequency was about 360 cycles per min. as compared with 135 for the spillway.

10. Shortly after 9:30 a.m. on May 26, an inspection of the downstream end of the needle valve, transition elbow and draft tube was started. Entrance to this portion of outlet was made through the manhole in the left side of the concrete anchor encasing the transition elbow near

the upstream end of the latter. An appreciable leakage past the coaster gate on the upstream end of the penstock made it necessary to close the valve while making this inspection, thus the seat ring of the nozzle or needle could not be examined except by entrance from the upstream side with the valve opened, the penstock drained, and the leakage passing through the valve to the draft tube pumps. A casual examination of the nozzle and needle was made from the downstream end with the valve closed, but there seemed to be no indication that cavitation had occurred. However, areas of the paint which were as much as 1/8 inch in thickness at many points on the needle tip downstream from the bronze seat ring, were chipped making the surface of the tip quite rough. It is believed that the needle tip surface should be smoothed and repainted. It is planned to perform this work on remaining units before placing them in operation.

Examination of the surface of the outer bend of the transition elbow disclosed many breaks in the paint, exposing or scarring the metal underneath. As these were on the surface of the outer bend where the flow from the needle impinges and is turned downward into the draft tube, they were believed to have originated from debris (rock, pieces of iron, wire and rods) flushed from the trashrack when the valve was operated with the coaster gate near the closed position. The same pitting was noted on the curved surface of the bottom of the draft tube where the flow from the transition elbow strikes and is turned horizontally toward the draft tube exit.

In many areas, where thin patches had been made, particularly in joints or cracks where the concrete had been stoned and the bond was poor, the concrete was torn out. This condition was due no doubt to water pressure entering through the cracks or seams forcing the poorly bonded areas to "pop out".

At many points the concrete edges adjacent to the metal noses of the draft tube piers, in both the top and bottom of the draft tube, were chipped as if pried out by a bar placed in the joints between the metal noses and the concrete. The cause of this condition was not apparent.

Several pieces of wire, one length of heavy gage about 6 feet long, and the rest short strands of light gage, were taken from the floor of the draft tube. These were believed to have been dislodged from the valve when it was operated during the unwatering of the outlet after the coaster gate had been closed, since they were not observed when the draft tube was entered for the first time before the inspection was made.

Careful examination of all interior surfaces was made for the purpose of locating the source of the cavitation indicated by the vibration and crepitation observed during operation of the outlet. Two areas having a spongy appearance and considered definitely the result of cavitation were located in the concrete surface just below the joint between the concrete of the anchor block and the transition elbow. These areas were near the ends of the arc of the upstream boundary of the elbow exit. Both were about 8 inches wide and extended approximately 12 inches below the joint.

At one point adjacent to the steel in the area on the right side, the concrete seemed to have been chipped out to a depth of approximately 1-1/2 inches. This condition was believed to be present before the test was started.

Below the last two or three weld seams at both sides and near the end of the transition elbow, small patches of paint were missing. This condition seemed to be the result of local cavitation, although no pitting of the metal could be detected.

Two areas on the original concrete of the draft tube just below the joint between it and the new construction, downstream and outward from the areas at the end of the elbow, had a slightly pocked appearance, but it was difficult to establish them as pitting due to cavitation. The boundary surface of the water passage upstream from each of these areas did not appear to form a continuous curve, but seemed to contain an abrupt change in slope, a condition conducive to cavitation in high velocity flow. That many of the discontinuities were contained in the design of this part of the structure was established when a study was made of drawings 222-D-9198 and -9250 after the next test.

11. Upon the completion of the inspection downstream, the needle was retracted to drain the water, which had ponded in the penstock due to the leakage past the coaster gate, permitting entrance to the outlet above the valve. Inspection of the inner surfaces of the 96-inch elbow and the upstream end of the valve disclosed many breaks in the painted surfaces. These were attributed to the impact of the objects carried by the outlet flow during the initial operation. Several lengths of small metal rod and strands of wire were bent across the upstream end of the bottom guide vane. These were removed. With the needle retracted and the penstock drained it was possible to wade the leakage flow and crawl on the horizontal vanes to the downstream end of the valve, Inspection of the needle and nozzle in the region of the seal disclosed areas of minute pock marks, sufficient only to brighten the metal, on the needle and nozzle downstream from every guide vane and on the seal ring of the nozzle downstream from the painted inside surface of the valve casting in regions where the paint was of sufficient thickness to form an offset between the valve casting and the bronze ring.

12. As the leakage past the coaster gate was appreciable, it seemed desirable to make an inspection to determine the cause. From a ladder hanging through the manhole a short distance downstream, it was observed that the tubing which covers the top seal had been torn from its mounting and much of it was visible from inside the penstock. The lower seal covering had been found previously in the draft tube. Because the leakage was appreciable, a more thorough inspection was not made, but it was considered advisable to repair the seals before conducting additional tests.

13. Because of the intensity of the vibration during the initial operations, it was considered inadvisable to operate the outlet for extended periods, but in view of the necessity of obtaining sufficient data to

determine what corrective measures would be required, minor alterations were made, the coaster gate seal repaired, and preparations made to operate the valve for several short periods. A second test, consisting of two periods of operation, was conducted on June 5 after the coaster gate seal had been repaired and several minor alterations were made to the vent system to permit the installation of gages and recording equipment. A 10-inch orifice was installed in the joint of the vertical riser of the air vent at about elevation 975, to measure the air being supplied to the valve at various openings and pressure taps provided at points one pipe diameter upstream and one-half diameter downstream of the orifice. A differential manometer gage was connected to the two leads from the taps and the low pressure line provided with a vacuum gage. A pressure-vacuum gage was installed in the cover plate of the 18-inch pipe passing through the concrete anchor block encasing the transition elbow to determine the pressure conditions in the dome below the elbow. Provision was made to install a riser on this pipe extending it above the tailwater elevation, to ascertain what effect upon flow conditions would result from its being open.

14. The repair of the coaster gate seals was completed, the gate raised from the penstock entrance, and the second test started shortly after 11:00 a.m. on June 5. The valve was opened by increments of 20 percent to the fully open position, with pauses of sufficient length only for obtaining readings on the pressure gages and the vibrometer. The needle was closed slowly to the shut-off position after a period of about 10 minutes. The pressure-vacuum gage in the cap of the 18-inch pipe in the concrete block indicated a fluctuation from negative to positive, with maximum values of negative 5 and positive 10 p.s.i., during the period of operation at full capacity. The fluctuation from negative to positive pressure was indicated by the check valve on the 6-inch discharge line from the paradox control. In the previous test this valve had indicated a steady flow of air into the dome of the draft tube, or a continuous negative pressure. Unquestionably the additional back pressure due to the increased tailwater elevation had raised the pressure in this region. The flow passing the dam during this test was about 318,000 c.f.s., giving a tailwater elevation of 969.4. This might have served to dampen the vibration of the system, since it seemed of less intensity than in the initial test. As no change in the unit, other than the installation of the 10-inch orifice in the vent pipe, could have affected this condition, and since this change was considered insignificant, the 10.3-foot rise in tailwater, due to the increased river flow, seems the only explanation. No change in the seismograph records, other than an increase in the maximum amplitude for the spillway, could be detected, however.

Slight movement was noted in the joint in the face of the powerhouse above the draft tube bridge deck between units R-9 and R-S. Readings of the vibrometer on the deck were: vertical, zero; east-west 0.006 inch; north-south 0.003 inch. Deflections on the concrete anchor and on the valve were not measurable.

The quantity of air being drawn in through the 18-inch vent by the valve seemed to be large at all times. The noise of the air passing through the vent orifice indicated the quantity at the fully open position to be less than for all except very small openings. Quantities computed for the 20 percent increments in ascending order were 8,040, 12,620, 12,870, 11,520, and 9,330 c.f.m. (60° F. and 29.92 inches of mercury), Figure 1.

During the ten minute operation with the needle valve fully open, the tailrace was examined for flashes of light discovered during the initial test. Intermittent flashes of brilliant light, resembling that of sheet lightning in the distance, were observed. Excessive turbulence downstream from the R-9 outlet caused by the spillway flow, made it difficult to ascertain if the light bands extended below the water surface. This was believed to be the case, however.

15. In view of the apparent decrease in the vibration and the desirability of operating the outlet at full capacity for a longer period before unwatering and inspecting the interior surfaces, it was decided to continue the operation during the afternoon. In addition, the operation would afford an opportunity to determine the opening at which the light phenomenon occurred, to obtain motion pictures, and to make additional observations concerning the vibration. The valve was placed in operation about 1:35 p.m. and opened to full capacity by the increments of 10 percent at two minute intervals. The tailrace was observed from the roof of the powerhouse and motion pictures which are still to be processed, were taken of the tailrace below the outlet before and during the test. There were no light flashes visible until a valve opening of 30 percent was reached. At this opening they occurred frequently. The frequency decreased from 40 through 60 percent, then increased rapidly from 70 percent to the fully open position. The occurrence was not regular and varied in extent, being of a singular nature much of the time, but often forming into a netwrok of brilliant, irregular, shimmering bands. As a rule, the phenomenon centered below the R-9 draft tube with the greatest concentration just downstream of the draft tube bridge deck, but extended occasionally into the area below bay R-7. It is believed that this phenomenon is associated in some way with the energy changes involved in the collapse of the cavities in the upstream end of the draft tube, but it is not possible to correlate it with the ever-changing crepitation. The phenomenon has been described by some as being similar to that observed when dynamite is discharged under water.

With the outlet closed, there was no perceptible vibration of the powerhouse roof from the spillway flow. Vibration of this part of the structure became noticeable as soon as the outlet was placed in operation, increasing until 30 percent opening was reached, then decreasing slightly to remain fairly constant through 60 percent opening and increasing rapidly as the needle was retracted beyond this point. The vibration was more intense over the bay containing the outlet unit than at any other point. A slight movement could be detected in the joint at the top of the face of the powerhouse between the R-9 and R-8 units. Closing of the needle was begun about 3:25 p.m., particular effort being made to move the needle slowly between the 5 percent open and closed positions, with the result that water did not spout from the air-vent inlet.

16. The outlet was unwatered for the second time on June 6 and an inspection made of the interior surfaces. Very little change was observed in the pitted areas on the needle valve. The minute pits on the surface of the needle and nozzle downstream from the guide vanes seemed to be more numerous, thus explaining the low crackling noise at the end of the valve, but those on the seat ring below the offsets between the paint and the bronze surface appeared to be unchanged. However, it is believed that the pitting in the latter case could be prevented by feathering the paint at the joint between the bronze seat ring and the valve casting. This work is to be performed on all units before they are placed in operation. The pitting below the guide vanes might be eliminated by drilling through the valve casting to the back of the bronze guide strips at their downstream end, then through the strips at these points admitting air to the trailing edges of the vanes. These openings could be controlled by pipe and valves. No changes will be made in this respect until a definite plan has been evolved and submitted for approval. There was slight evidence of pitting on the surfaces of the needle tip and on a few of the babbit plugs over the screw heads in the bronze rings. However, the marks were so scattered in most cases as to make their origin uncertain. The importance of smooth continuous surfaces in high-velocity flow is shown clearly by this condition.

The breaks in the concrete edges adjacent to the metal noses of the draft tube piers appeared to be unchanged from those observed during the inspection following the initial test. The chipped edges shown adjacent to the pier nose on the attached photographs are typical of this condition, Figure 2 (photo #13046).

Much of the paint had been removed from the center portion of the outer bend of the transition elbow, and some from the inner bend near the upstream end of the elbow, as if worn away by material suspended in the flow. Areas of paint were missing at the downstream sides of several of the welded sections of the elbow, directly upstream from the ends of the arc at the back of its exit, Figure 3, 4, and 5 (photos #13044, and #13042, and #13051). These results from cavitation occurring immediately downstream from the welded seam above. The welded seams and the joints of the elbow combine to form a boundary of diverging surfaces. A region of sub-atmospheric pressure forms immediately downstream from each of the welded joints and the resulting cavitation cavities collapse to pit the surface as the pressure rises in the area just above the next welded joint. That this condition exists at the outer limits of the inner cirve of the elbow and not at other points is due to the fact that the flow is similar to that in sharp bends (considering the axis of the bend as being somewhere between the vertical and hroizontal planes) and this region is one where comparatively low pressures exist. It is believed that the conditions in these regions can be corrected by grinding the weld seams from and rounding the joints. However, there is a possibility that a thin wedge-shaped fillet of sheet steel or weld metal the thick edge of the wedge coinciding with the end of the elbow, placed over the pitted area and extending to the upstream edge of the last section of the steel elbow will be required to correct the condition in and just below the last section of the elbow. Such fillets will not be installed unless proven necessary after tests have been made with the joints ground.

A patch of concrete 30 by 6 by 4 inches deep was torn from its recess on the upstream side of the seam of the slightly depressed joint in the floor to the left of the draft tube centerline several feet upstream from the draft tube pier noses, Figure 6 (photo #13045). Examination disclosed the recess to be wedge-shape with the thick part of the wedge at the surface. It was believed to have been lifted out by pressure developed in the seams of its boundary. Patches at other points were undisturbed. It was not considered advisable to operate the outlet until the recess had been repatched, thus the test to ascertain the effect of admitting air to the dome in the concrete block below the transition elbow was postponed. However it is doubtful if it would be effective since it is not possible for air in this region to reach the critical points.

Many thin stoned patches in and near the joints in the floor of the vertical curve at the back of the draft tube had been torn out in addition to those noted during the previous inspection. These will not be replaced since they form only minor roughness and no doubt would be torn out again when subjected to the high velocity flow.

The pitted areas in the concrete adjacent to the exit of the elbow immediately below the areas from which the paint had been removed are parts of the areas resulting from the conditions created by the last welded joint of the transition elbow. This is shown clearly in Figures 3 and 4. A wedge of concrete plastered on the curved wall below the exit of the transition elbow may be seen in these figures also. The wedge was placed when the curve of the elbow exit failed to coincide with and extended over the concrete immediately below in this region. The face of this wedge slopes back from the vertical plane to the wall of the dome inside the concrete anchor block. This in itself would produce a point of inflection at the back edge of the transition exit of the inner curve if the last section of the elbow terminated in the vertical plane. This is not the case, however, as the surface of this section slopes downstream at an angle of at least 4-1/2 degrees at the centerline. This characteristic, evolving from the segmental construction of the elbow, is shown clearly in the side elevation, drawing 222-D-9187. In addition to these two factors, the wall of the dome within the concrete anchor block flares outward over most of the length of the elbow exit and to its right, producing an overhang which adds to the discontinuity. This condition is shown in section F-F, and Y-Y, drawing 222-D-9250. Although the three factors mentioned above are additive insofar as the discontinuity at the elbow exit is concerned, any one of the three are considered of sufficient magnitude to create a region of sub-atmospheric pressure capable of producing cavitation.

Small discrepancies in the actual construction limits of the old concrete and those given on the drawing have resulted in an abrupt transition between section h-h, drawing 222-D-9250, and the old construction. This condition is shown, though not very clearly, in Figures 7 and 8 (photos #13041 and #13043). Thus far, it seems to have had no detrimental effect upon the action of the outlet.

That pitting has occurred directly under the elbow at and below the joint between the old and new construction, as well as downstream from it and extends in varying degree across the surface over which the flow passes is considered evidence that a region of subatmospheric pressure, of the proper magnitude to cause cavitation, exists behind the valve jet above this elevation. The bands of pitting along the walls downstream from the outer extremities of the exit of the transition elbow indicate that the zone of cavitation is sealed along the sides by the flow as it spreads and plunges to the vertical curve in the floor of the draft tube. The dotted ink lines on Figure 9 (photo #13050) show the approximate limits of the cavitation zone. It is believed that the admission of air into the dome of the concrete anchor block through the 18-inch pipe at its crown will not be of noticeable benefit until some passage has been provided to convey the air from the upper region of the dome to the underside of the jet as it plunges from the exit of the transition elbow. Apparently the air taken in by the valve does not reach this cavity in sufficient quantity to relieve the negative pressures to prevent the cavitation. Since the zones of cavitation in the R-9 outlet are sealed from the air in the dome of the anchor block and since they originate in and near the elbow exit, there should be very little influence from the variation in tailwater, thus any solution to the problem under present conditions should serve as well for lower tailwater elevations.

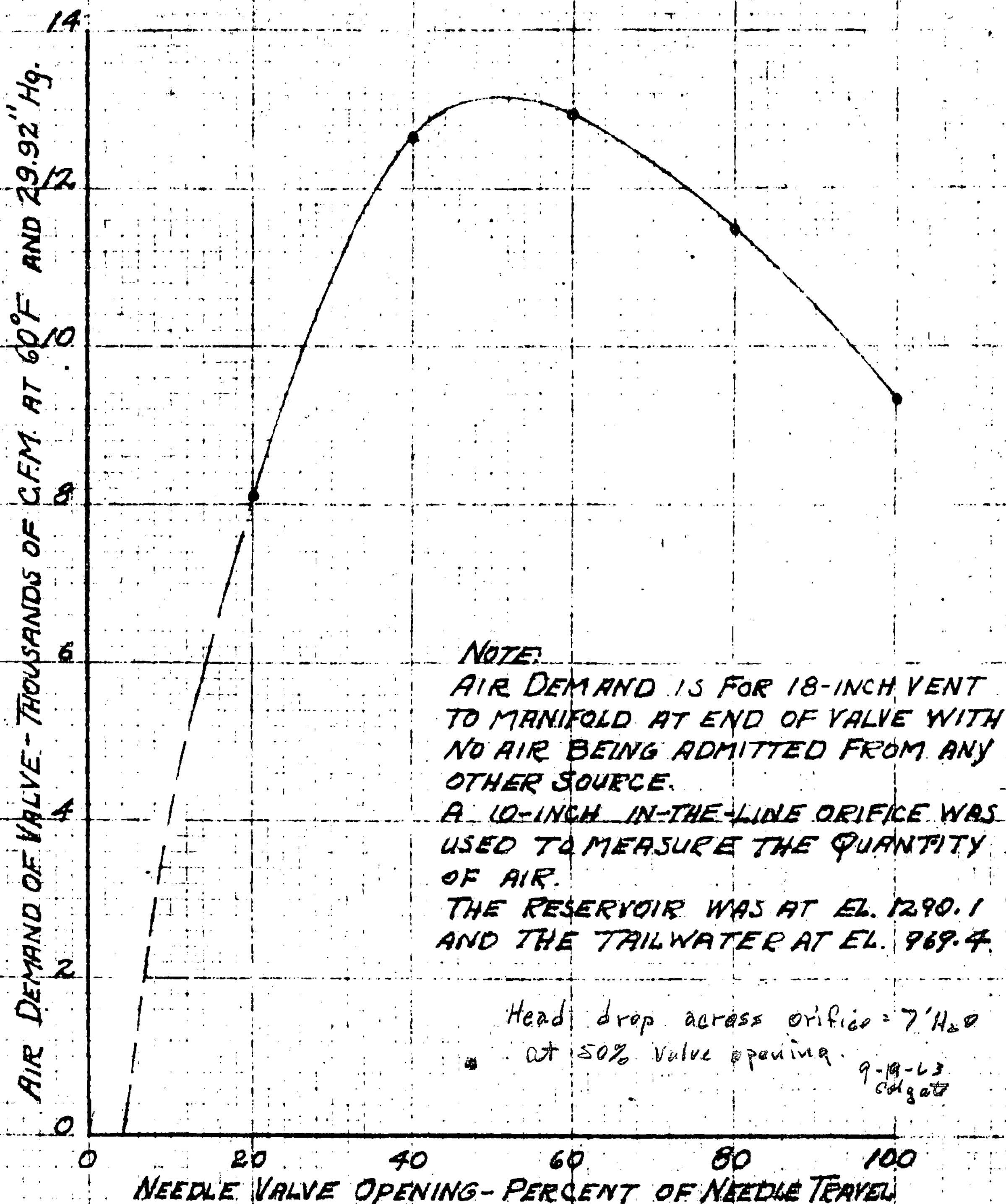
From a study of the conditions existing in the R-9 outlet and the drawings of the installation, it appears that it would be impossible to supply continuous bounding surfaces, coinciding or encroaching slightly on the flow, without altering the old construction. It seems, therefore, that the installation would have been improved by locating the exit of the elbow nearer the center of the draft tube entrance, permitting complete aeration at this point. Since it is not practicable to change the position of the embedded elbow in the completed units, other corrective measures must be taken to eliminate the conditions creating the zones of subatmospheric pressure which induce the cavitation causing the vibration and pitting. Four possible methods of correcting the condition downstream from the elbow seems to be indicated at the present time. They are (1) locating the boundaries of the regions of sub-atmospheric pressure and drilling the anchor block to install adequate venting facilities with provision to prevent the flow of water from the tailrace when the unit is not operating; (2) chipping the concrete from the back of the anchor block and the draft tube to a depth sufficient to permit the construction of a new continuous bounding surface in this region; (3) welding an extension to the back of the exit of the elbow, sloping it downstream to force the flow to spring free of the back wall to permit aeration of this region and restrict the flow on the inner band of the elbow, thereby raising the pressure within; (4) and chipping the concrete wedge from the wall below the exit of the transition elbow, extending and possibly enlarging the groove formed thereby beyond the ends of the exit to permit aeration of the jet as it leaves the elbow, smoothing the surface of the wall where the flow is likely to contact it, and possibly chip and grind the surfaces in the vicinity of the joint between the old and new construction to minimize the discontinuity in this part of the structure. The fourth treatment mentioned above seems most feasible, and plans are being made to proceed with the alterations indicated. In any case, the treatment of the weld seams and joints at the sides of the steel elbow near its exit, mentioned previously, will be necessary.

For the next trail test, the weld beads and joints of the transition elbow will be ground in the regions where cavitation has occurred. The metal wedges mentioned previously for the regions of cavitation and pitting in the last section of the elbow are to be omitted in this test. The concrete wedge in the wall of the anchor block below the elbow exit will be chipped out and the groove enlarged and extended beyond the ends of the exit. All rough seams and areas in the new construction, where the flow is likely to contact the surface will be ground smooth and the existing pits filled with grout and smoothed with carborundum stone. No chipping or grinding to change the limits of the old construction where it joins the new is to be done unless the requirement of such treatment is established by the trial test. The Penstock hemispherical bulkheads are to remain in place on all units until the alterations indicated by the tests on the R-9 outlet have been made. It is hoped that the elimination of the cavitation in the outlets will reduce the vibration sufficiently to remove any concern during long periods of operation.

Encl. Figs.

F. A. Banks

FIGURE 1



GRAND COULEE DAM

AIR DEMAND OF 84-INCH NEEDLE VALVE IN SPILLWAY BY-PASS OUTLET

J.W.B. 6-12-45

L-4168

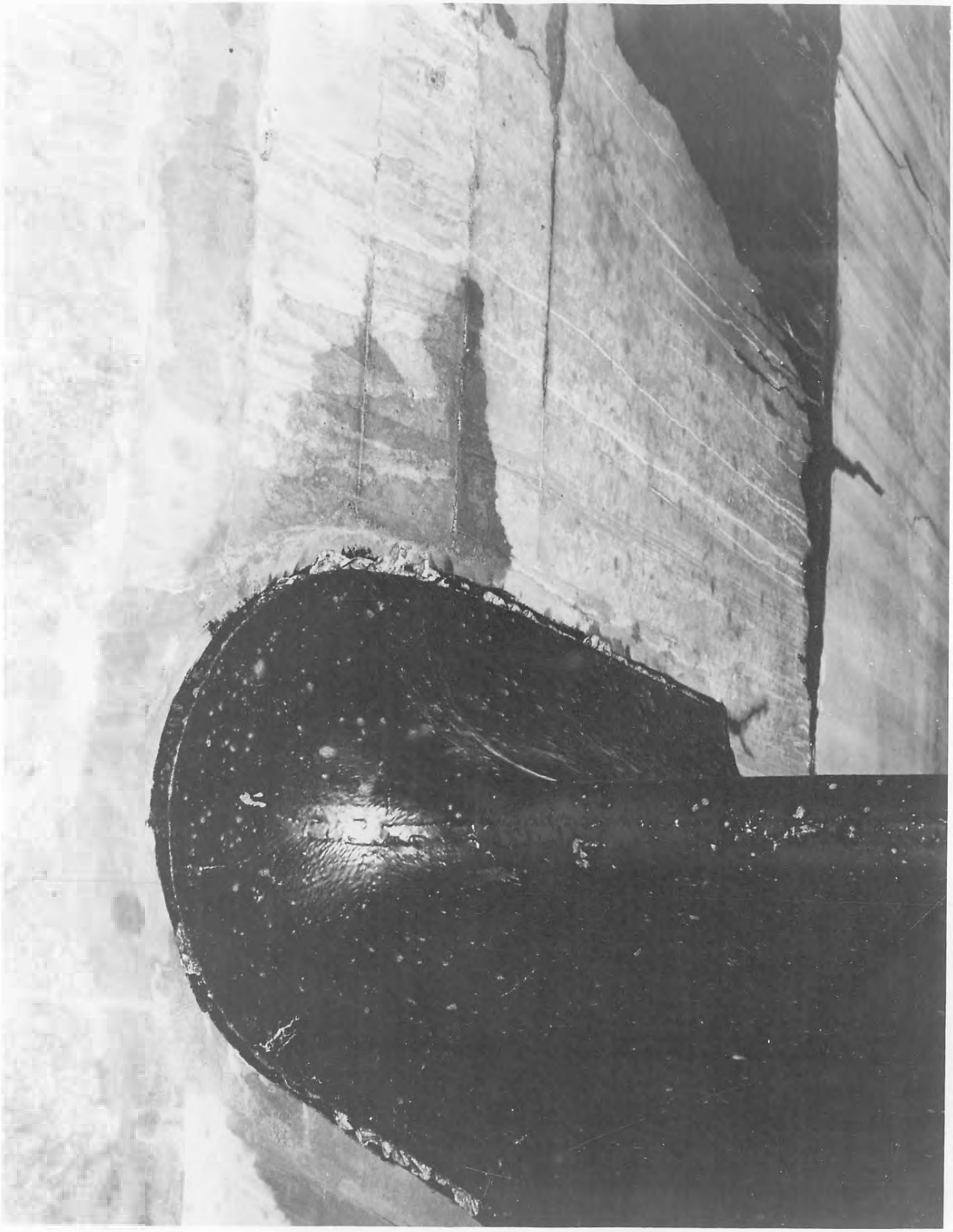


Fig. 2. Photograph 13046-3, June 7, 1945: View from floor of draft tube showing chipped edges in concrete adjacent to top of the metal pier nose in draft tube R-9.

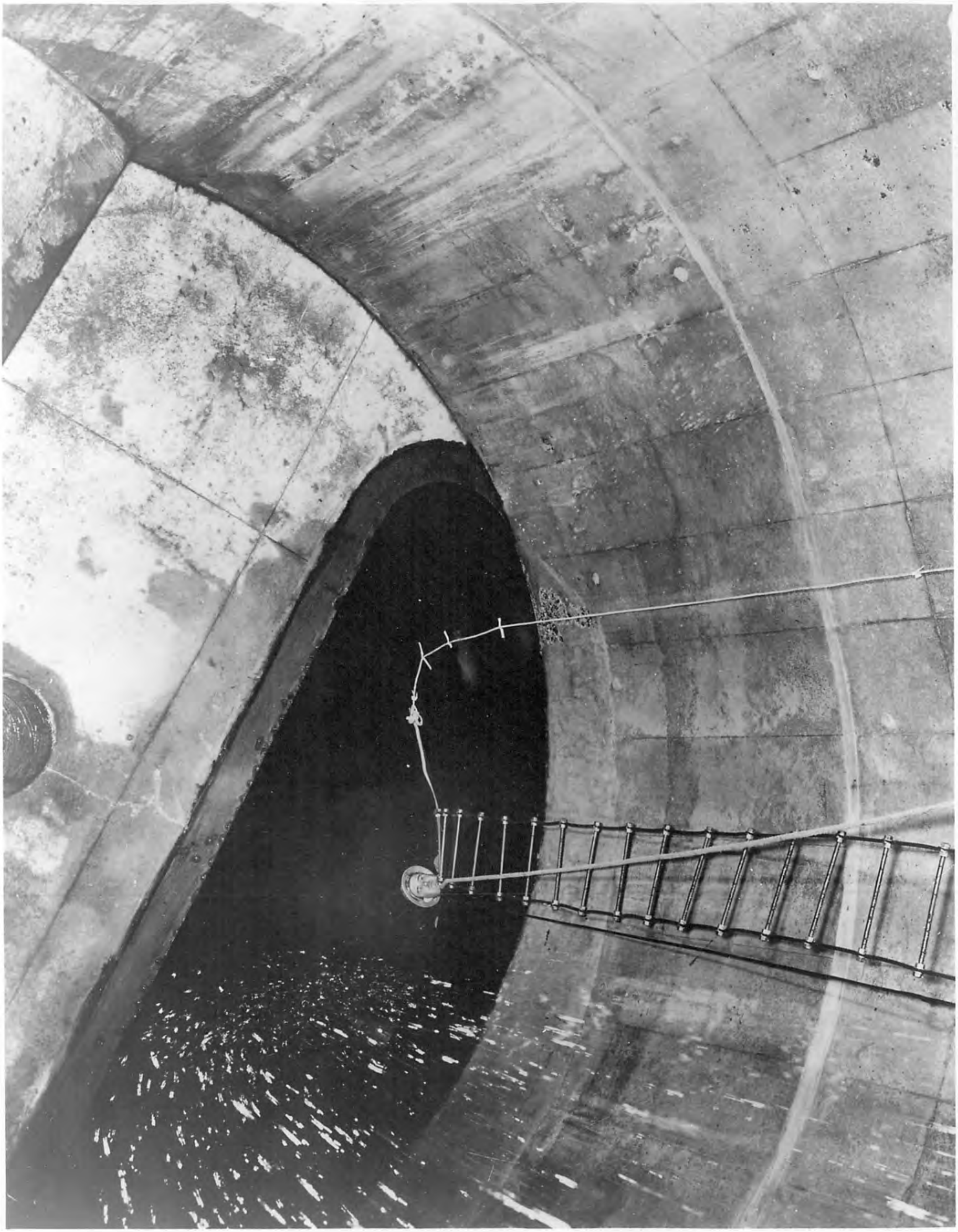


Fig. 3. Photograph 13044-3, June 7, 1945: View from floor of draft tube showing pitting by cavitation in the inner curve at the left side of the steel elbow and in the wall of the anchor block immediately below, after operation of the R-9 outlet for tests on May 25 and June 5, 1945. Discontinuities in flow boundary accentuated by small rope passing over damaged areas.

Fig. 4. Photograph 13042-3, June 7, 1945: View from draft tube floor showing pitting by cavitation in the inner curve at the right side of the steel elbow and in the wall of the anchor block below after the operation of the R-9 outlet for tests on May 25 and June 5, 1945.

Fig. 5. Photograph 13051-3, June 7, 1945: View from floor of draft tube showing pitting by cavitation in the inner curve at the left side of the steel elbow and in the wall of the anchor block and draft tube directly downstream, after operation of the R-9 outlet for tests on May 25 and June 5, 1945.

Fig. 6. Photograph 13045-3, June 7, 1945: View from floor of draft tube showing recess in joint upstream from draft tube piers from which patch has been torn by flow from 84-inch needle valve, after operation of the R-9 outlet for tests on May 25 and June 5, 1945.

Fig. 7. Photograph 13041-3, June 7, 1945: View from floor of draft tube, showing pitting by cavitation at the junction of the anchor block with the old construction in the vertical curve at the back of the R-9 draft tube after operation of the outlet for tests on May 25 and June 5, 1945.

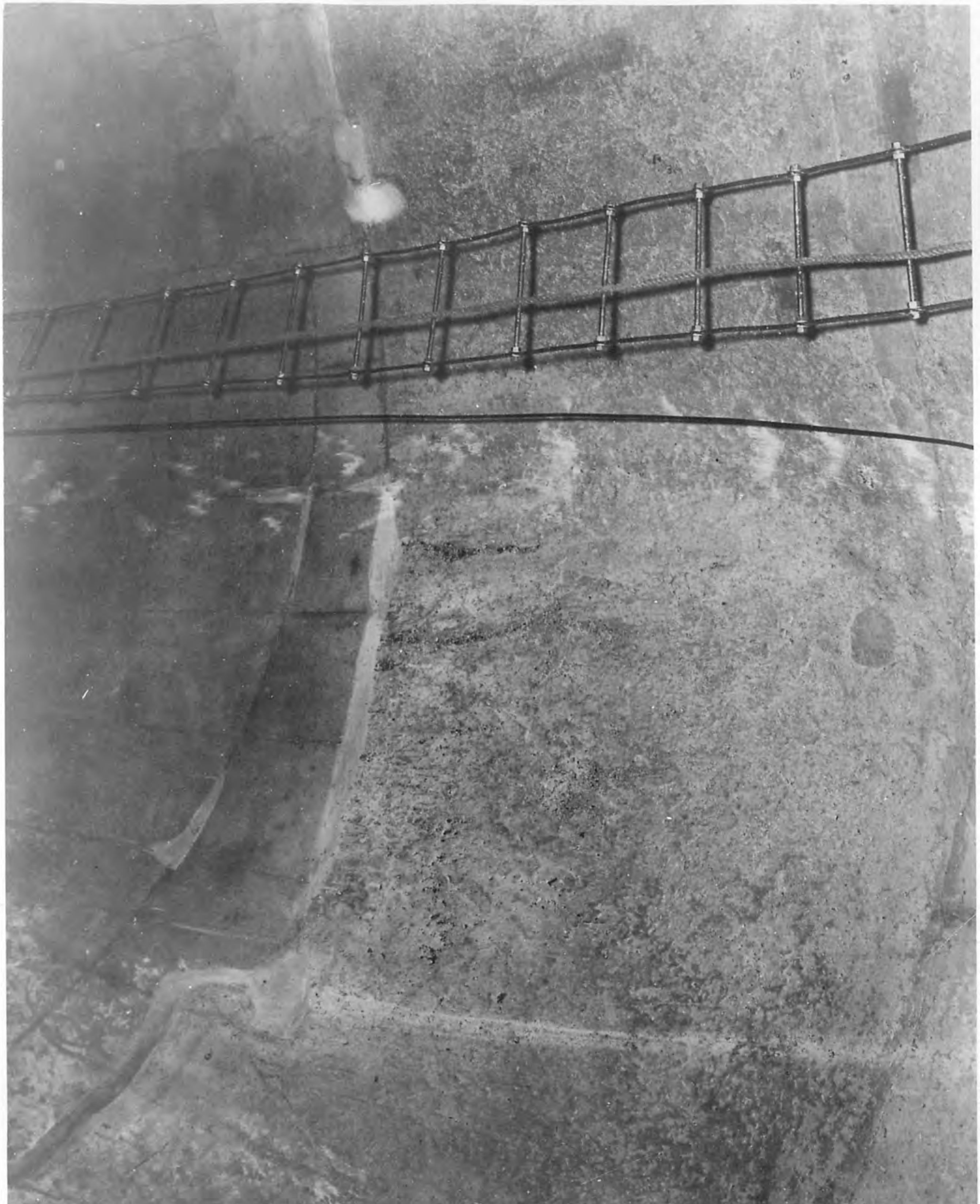


Fig. 8. Photograph 13043-3, June 7, 1945: View from draft tube floor showing pitting by cavitation at the junction of the anchor block with the old construction in the vertical curve at the right side of the R-9 draft tube entrance below the transition elbow after operation of the R-9 outlet for tests on May 25 and June 5, 1945.

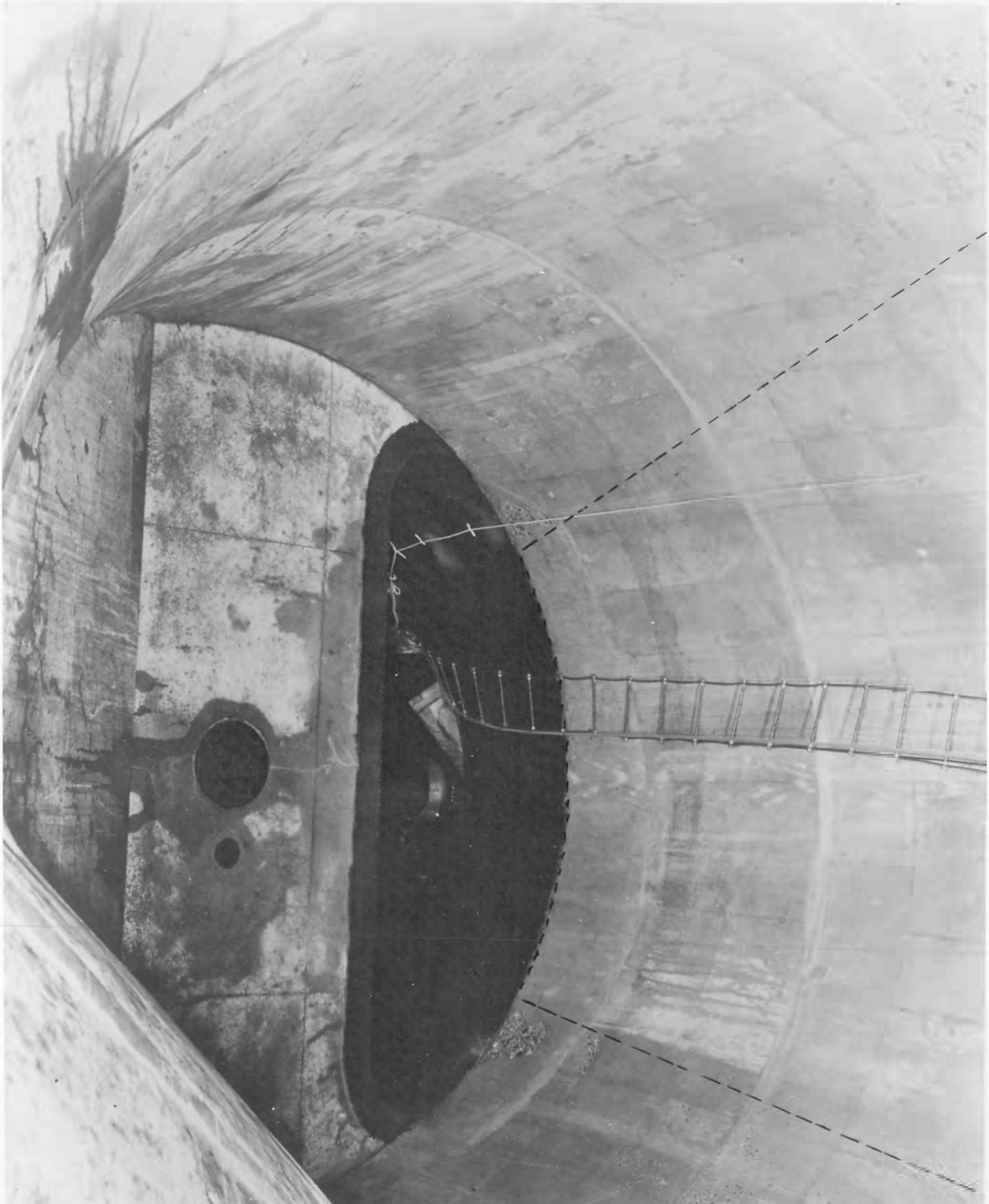


Fig. 9. Photograph 13050-3, June 7, 1945: View from floor of draft tube showing relative location of pitting by cavitation in inner curve of transition elbow and concrete wall of anchor block and draft tube directly below, after operation of the R-9 outlet for tests on May 25 and June 5, 1945.

August 27, 1945

Memorandum for Construction Engineer
J. W. Ball

Subject: Condition of 84-inch needle valve outlet after test operations of August 7, 8, and 9, 1945--Grand Coulee Dam-- Columbia Basin Project

INTRODUCTION

1. Resumption of tests on the 84-inch needle valve outlet.

Testing of the 84-inch needle valve in bay R-9 of the right powerhouse was resumed on August 7 after minor alterations and repairs had been made for the purpose of improving flow conditions which caused damage to the interior surfaces of the transition elbow, anchor block and draft tube during tests conducted on May 25 and June 5. The results of the previous tests, discussed in a letter from the Supervising Engineer to the Chief Engineer, "Test operation of 84-inch needle valve bypass outlets in right powerhouse--Columbia Basin Project", dated June 26, 1945, are summarized briefly in subsequent paragraphs to recount the occurrences leading to the recent test, the results of which are the subject of this memorandum.

2. Summary of previous operations.

Because of severe vibration and the indication of cavitation in the outlet during the initial operation the needle valve in bay R-9 of the right powerhouse was operated for only a short period for the first test. After discharging at various openings for approximately two hours, the outlet was unwatered for inspection. There was some pitting due to cavitation but the areas were not defined clearly and further testing seemed desirable. However, the seals of the penstock coaster gate had been damaged during the test and it was considered advisable to repair them before continuing the testing. While this repair work was being performed minor alterations were made to the vent system to permit the installation of equipment and gages for measuring the quantity air entering the vent below the valve and for recording the pressure in the 16-inch pipe in the dome of the concrete anchor block. The work was completed and a second test conducted on June 5. An inspection of the interior surfaces after operating the valve for an hour at various openings and approximately 1½ hours at full capacity disclosed pitting by cavitation on the inner curve of the transition elbow, in the walls of the anchor block below the upstream edge of the elbow exit, and in the curved surface at the back of the draft tube. Other damage included the tearing out of a patch near the construction joint 17'-9" upstream from the metal pier noses; scarring of the valve, transition elbow, and draft tube by debris passing through the outlet; and the breaking of the concrete edges at several points adjacent to the tops and bottoms of the pier nose castings. It was evident from the results of this test that an improvement of flow conditions in the transition elbow, the anchor block and the draft tube would be necessary if satisfactory operation for extended periods was to be expected.

3. Alterations to the outlet after operations of May 25 and June 5.

The following alterations to the outlet structure were made after a study and discussion of the results of the test operations of May 25 and June 5:

(1) The thick accumulation of chipped paint was removed from the needle tip of the valve, all screw heads dressed flush with the surface and the needle tip repainted.

(2) The weld beads at the joints in the inner curve of the steel transition elbow on both sides of the center line where pitting due to cavitation was indicated were chipped and ground and all areas from which the paint had been removed by cavitation or abrasion during the test were smoothed and repainted.

(3) A groove six inches deep and six inches high at the back with the bottom surface sloping 45 degrees downward toward the center of the anchor block was chipped in the wall of the anchor block below the exit of the steel elbow. The groove was extended approximately 30 inches beyond each end of the exit opening and all concrete which would protrude into the flow from the elbow was removed from the wall of the anchor block.

(4) All pitted areas in the wall of the anchor block below the elbow exit and in the curved surface at the back of the draft tube were chipped and repaired and all prominent irregularities removed from the wall.

(5) The patch near the construction joint 17'-9" upstream from the nose of the left draft tube pier was replaced, keyed and dowelled.

The walls of the anchor block and draft tube as they appeared before the test of August 7 after the above alterations and repairs were made are shown in Figure 1 (Photograph 13213-3).

When the alterations enumerated above were completed and sufficient time allowed for curing the new concrete preparations were made to resume the test operations. Because of the indication that severe subatmospheric pressures existed in the dome of the anchor block during the initial tests, a 10-foot extension with a 10-inch orifice and suitable pressure taps was placed on the 18-inch pipe in the top of the dome. The purpose of this extension was to raise the end of the pipe above tailwater elevation so that it might be left open to ascertain whether or not venting at this point would improve the operation of the outlet and to measure the amount of air entering at various valve openings. The preparations were completed and the test began at 9:30 a.m. on August 7. The test consisted of two operations, one of six hours duration on August 7 and the other of 17 hours on August 8 and 9. The results of these operations, the corrective treatments indicated and plans for future tests are discussed in detail in subsequent sections of this memorandum

RESULTS OF 6 HOUR OPERATION ON AUGUST 7

4. Air Vents.

In the period of operation on August 7 the valve was opened by increments of 20 percent of the needle travel to the fully open position with pauses at these openings for observing the action of the vents and recording data to determine the quantity of air passing through them. A surge was observed in the 18-inch vent to the dome of the anchor block, with the water in the pipe rising and falling about 5 feet at valve openings to and including 40 percent. As the opening was increased to 60 percent the water surface was not visible in the pipe, but a wide variation in pressure within the,anchor block dome was indicated by the alternate inward and outward movement of large quantities of air. The movement of air was in both directions at 80 percent opening but high velocities into the vent existed most of the time. Though there was a wide variation in the pressure at the orifice with the valve operating at full opening, the air flowed into the dome at all times. The quantities entering through this vent for the 60, 80, and 100 percent openings (based on the mean pressure differential across the orifice and standard conditions) were 6,000, 11,000, and 12,000 c.f.m., respectively. Quantities of 2700, 3200, 3100, 2700 and 1100 c.f.m. recorded for the vent to the needle valve openings of 20, 40, 60, 80, and 100 percent seemed to be too small. The correctness of this data should be verified when the next test is conducted. A small amount of water spouted from both vents when the valve was closed.

5. Vibration from operation of the outlet.

The operation was quiet for openings to 60 percent, where some noise with little vibration was noted. There was some vibration with crackling and popping sounds at 80 percent opening. The vibration and crepitation increased as the needle was retracted to the fully open position, but neither was as intense as in the tests of May 25 and June 5. The vibrometer recorded a deflection of 0.002 inch in the east-west direction and a slight tremer in the north-south direction when placed on the draft tube bridge deck. The readings for the test of June 5 were 0.006- and 0.003-inch, respectively. No vertical movement was recorded during either of the test operations. No difference in vibration from previous operations could be detected from the seismograph records.

The valve was closed by increments of 5 percent to 60 percent opening to study the variation in the intensity of the vibration. At 95 percent opening the vibrometer recorded 0.001 inch in the east-west direction and a slight tremor in the north-south. At 90 percent opening there was only a slight tremor in both directions. There was no appreciable vibration below 80 percent opening.

A noise resembling cannonading in the distance was noted from the draft tube bridge deck when the outlet was discharging at full capacity. It seemed concentrated in the left passage of the draft tube and its frequency and intensity decreased as the needle moved toward the closed position.

6. Light Phenomenon in the tailrace.

After operating at partial openings for a short period the valve was opened completely and allowed to remain in the position until 3:30 p.m. The light phenomenon reported for the previous tests was present, but to a lesser degree, the flashes being concentrated below the center and left passages of the draft tube and never extending into bay R-8. The valve was closed slowly at the end of the test period to ascertain at what opening the light phenomenon disappeared. The frequency and intensity decreased slowly, the light bands becoming faint and very infrequent at 50 percent opening and disappearing between 30 and 40 percent. As movies taken during the test of June 5 failed to show the flashes clearly another attempt was made to record the phenomen by motion pictures. The film is still to be processed.

7. Damage to the interior surfaces of the outlet.

The outlet in bay R-9 was unwatered and an inspection made of the interior surfaces. Pitting due to cavitation had occurred on the concrete walls of the anchor block just below the aeration groove near the ends of the exit of the transition elbow. (Figure 2, Photograph 4930-2). Areas of paint had been removed from the surfaces of the elbow sections just above these points. The condition was similar to that noted in the previous tests. There was no pitting at the back of the draft tube and the anchor block as in the previous tests. The aeration groove below and at the back of the transition elbow eliminated this action. However, the new patch just upstream from the construction joint in the draft tube 17' -9" from the nose of the left pier had been torn from its recess again and there were signs of pitting due to cavitation along the upstream edge, to the left and right at about the same elevation and downstream from the recess. The five dowels of reinforcing steel remained in the recess, but the grout around them had been removed to a depth of 1 to 2 inches below the bottom of the recess. There was definite indication that the pitting in this area resulted from cavitation, which was not the case in the test of June 5. No change in the condition of the joints between the pier nose castings and the concrete surfaces of the draft tube could be detected and no other change in the surfaces of the outlet were apparent. Considering the results of this test, a decision was made to operate the outlet for an additional period of approximately 16 hours, or a total of 22 hours, to more clearly define the cavitation and pitting zones.

RESULTS AFTER 23 HOURS OPERATION AT FULL CAPACITY
ON AUGUST 8 and 9.

8. Light Phenomenon in the Tailrace.

At 10:00 p.m. on August 8 the tailrace was observed to ascertain if the light flashes were visible in the darkness. None were observed, thus it was concluded that the phenomenon results from changes in the refractive and reflective qualities of the water produced by pressure waves emitting from the collapse of cavitation cavities in the outlet structure.

9. Worn Surface of the manhole wall and cover.

Much of the weld bead inside the flange of the manhole to the transition elbow was worn away near the top of the opening. The wear decreased gradually from this point to the invert where only a part of the high ridges on the bead had been removed. At several points some of the metal adjacent to the gasket surface of the flange had been worn away to form a very sharp edge. The crown of the 30 inch pipe just inside the flange was worn, the paint and surface of the metal being removed for a distance of 6 to 8 inches at the top and decreasing rapidly toward the horizontal centerline. The surface of the cover plate near the top to the pipe was worn similarly, but the area did not extend more than 1/2 inch inside the wall of the pipe, at the crown and decreased toward the horizontal centerline. All surfaces were wavy but had the appearance of having been polished. Either cavitation or whirling dust particles might have been the cause. This condition had been noted after previous operations but the area had been so small and the change so minor that it was not reported.

10. Condition of the needle valve.

Except for an area below the seat ring on top of the needle tip of the 84-inch valve, the new coat of paint was intact. The paint in this area had the appearance of being peeled from the surface by high-velocity flow or abrasion. There appeared to be no change in the condition of other parts of the valve.

11. Condition in the transition elbow.

The areas on the surface of the inner curve of the transition elbow from which the paint had been removed during the operation on August 7, had increased in size. (Figure 3, Photo 13247-3) Although only one area about 6 inches in diameter, 3.5 feet to the right of the centerline on the seventh section of the transition elbow had a spongy appearance, all seemed to have been caused by cavitation. Apparently the chipping and grinding of the weld beads at the joints between the sections of the elbow had not reduced the discontinuities in the bounding surface of the elbow sufficiently to eliminate the cavitation. The position of the areas was established for future reference if it becomes necessary to correct flow conditions in the elbow (Figure 4).

12. Pitting of walls of anchor block.

The pitted areas on the walls of the anchor block just below the elbow exit were larger and deeper than for the operation of August 7. The change on the right side was small while that on the left was quite extensive, the concrete being plucked to a depth of about three inches in two areas, (Figure 3, Photo 13247-3). A comparison of the conditions after 23 hours operation with that after 6 hours shows that the second and lower pitted area on the left side formed during the last 17 hours of operation. It is believed that the second area resulted from a local condition caused by the first after it reached sufficient proportions to induce a discontinuity in the flow boundry. If this is the case pitting by cavitation might be considered progressive and considerable damage would result before the boundry is sufficiently removed to cause the pitting to cease.

13. Conditions at the back of the draft tube.

There was still no indication of pitting at the back of the draft tube or where the old and new construction joined proving the aeration groove installed at the back of the elbow exit to be effective in this zone, (Figure 5, Photo 13246-3).

14. Damage in the region of the patch recess.

After a total of 23 hours operation a band of shallow pits had formed in the concrete surface along the top and both sides of the recess from which the patch had been torn during the first six hours, (Figure 6, Photo 13242-3). The area at the downstream edge and to each side of the recess was pitted severely for a distance of five feet below its upper edge, exposing several bars of reinforcing steel, (Figure 7, Photo 13252-3). All the wire ties at the intersections were missing and the bars were battered severely where they contacted one another during the test. The wear in the east-west bars was to the left of the natural intersection, indicating large transverse forces. A short section was missing from one of the bars. The metal of the broken ends was bright so the breaks were attributed to severe vibration induced by the flowing water. The maximum depth of the pitted zone was 18 inches at the construction joint and the area, including the recess, was about five feet in diameter. The source of the cavitation producing this damage was not apparent immediately, but was believed to originate from either irregularities in the flow boundary or the tendency of the high-velocity jet from the elbow to deflect after striking the curved surface. A survey of the concrete surface adjacent to the pitted area, made several days after the inspection, disclosed the first to be the more likely cause. Sections taken across and perpendicular to the construction joint 17' -9" upstream from the draft tube piers showed a discontinuity in the surface about one foot upstream from the joint, with the surface receding suddenly at this point to meet the concrete below the joint. The surface receded a maximum of 3/4 inch to the right of the patch recess. A typical section showing the discontinuity, and a grid system showing the extent of the survey, the low area and the boundaries of the new patch, which is to remove the discontinuity, are contained on figure 8.

15. Condition of the Concrete edges adjacent to the pier nose castings.

There had been a substantial increase in the amount of concrete broken from the edge of the joint between the concrete surface of the draft tube and the nose casting of the left pier, (figure 9, Photograph 13248-3). The cause was not apparent as examination of the pier noses indicated no movement. However, the cracks in the concrete portion of the piers immediately downstream were more prominent than on previous inspections. The condition might be due to zones of local cavitation caused by water passing through the joint at high velocity.

16. Concrete missing from the hole in the side of the pier nose casting.

A portion of the concrete filling the lower 6-inch hole in the right side of the nose casting of the right pier was missing (figure 10, Photograph 13250-3). The cavity had the appearance of a fracture caused by a severe blow. No cause for the break was apparent. A small corner of the concrete in the hole immediately above was missing. Inspection disclosed a sizeable void below the surface adjacent to the casting.

17. Damage to gratings to the draft tube unwatering valves.

Two of the cast gratings to the draft tube unwatering valves were missing from their recesses in the center passage between the draft tube piers. Evidence was that the gratings had been torn from the anchor bolts by severe vibration and moved into the tailrace by the outlet flow. Some of the anchor bolts had been flattened on the upstream and downstream side, the nuts were missing from many of them, the threads on all had incurred various degrees of damage and many were bent or stretched, (figure 11, Photograph 13249-3). One bolt in the right pier had been stretched so severely that the nut would almost slide back and forth over the threads. Apparently the vibration loosened the gratings sufficiently to allow the bolts and nuts to pass through the slots in the top of the gratings, transferring the entire force to the bolts passing through the bases and eventually tearing the gratings from these bolts. Since the nuts were missing from all three of the lower bolts in the left pier it is presumed that this grating was torn out as a unit, possibly without damage. The presence of two of the three nuts in the right pier indicates damage to the grating torn from this pier.

Examination of the two remaining gratings disclosed the nuts to appear tight with the paint covering unbroken. However, several of the washers could be moved easily. Such conditions may or may not have existed on all of the gratings prior to the test operations on the R-9 outlet. Tremendous oscillating forces must exist in the draft tube to remove the gratings whether or not they were anchored tightly. Pressure changes due to either cavitation or variations in the flow region would seem the most logical sources of such oscillation. The gratings in all the draft tubes in the right powerhouse should be tightened thoroughly before the outlets are operated.

CORRECTIVE MEASURE INDICATED

18. Worn surface of the manhole wall and cover.

The reason for this wear has not been determined and some effort should be made to establish its source. It has been agreed that a pressure tap be installed in the cover to ascertain the pressure conditions within. Should low pressures be present a small vent to the manhole might be a solution. Another treatment would be the installation of a removable filler inside the manhole with its surface coincident with the inner surface of the transition elbow.

19. Surface of the Needle tip.

The area of paint on top of the needle tip, damaged during the operation of August 7, 8, and 9, should be replaced to ascertain if the damage was caused by cavitation, by abrasion from materials (believed to be sand) entering through the 18-inch vent or by high velocity flow over a roughened surface.

20. Cavitation in the surfaces of the transition elbow.

The spongy appearance of the small area in the seventh section of the transition elbow indicates that conditions in the elbow will become critical in a short time if the outlet is to be operated continuously at 100 percent. Whether or not there is cavitation at smaller valve openings has not been determined. No alteration is to be made to the elbow at this time to correct the condition since it is desired to ascertain the valve opening at which cavitation occurs. It is planned to repaint the elbow and determine the critical opening in the next test. Should this opening be too small either of two treatments might be used. The critical areas might be vented by cutting a strip from the metal wall of the transition elbow between the air manifold below the valve and the joint between the last two sections of the elbow, chipping a groove in the surface of the concrete anchor block in this opening, replacing a metal strip with holes for venting and connecting the upstream end of the groove to the air manifold or through it to the atmosphere. The second treatment, possibly the most feasible, was outlined in the letter from the Supervising Engineer to the Chief Engineer, mentioned in paragraph 1 of this memorandum. The treatment involved the placing of wedge-shaped fillets of sheet steel or weld metal over the cavitation and pitted zones, forming a blister-like surface over the critical areas on the inner surface on both sides of the elbow centerline.

21. Pitting in the walls of the anchor block.

The pitted areas in the wall of the concrete anchor block immediately below and near the ends of the elbow exit are caused by cavitation in the elbow, thus the action would be eliminated by correcting the conditions in that part of the structure.

22. Damage in the vicinity of the patch recess.

The pitting near the joint 17' -9" upstream from the draft tube pier noses and in the vicinity of the patch recess is no doubt due to the discontinuity shown by the survey made of this portion of the structure. The removal of this discontinuity be increasing the size of the new patch and placing the surface of this patch according to a predetermined curve should eliminate this condition. The extent of the patch to be installed prior to the next test is shown in figure 8.

23. Concrete edge adjacent to the pier nose casting.

Some effort should be made to prevent the breaking of the edge of the concrete adjacent to the pier nose casting. It is understood that the cracks in the piers downstream from the castings are to be grouted and the broken edge repaired. This treatment should prove adequate for the next test.

24. Concrete in the hole in the pier nose casting.

It seems advisable to replace the concrete missing from the bottom hole in the right side of the right draft tube pier for the next test and an attempt made to determine the cause of the fracture.

25. Gratings to the Draft tube unwatering valves.

It does not seem necessary at this time to replace the gratings missing from the center passage of the draft tube. However, the anchor bolts in the two remaining gratings, in the right side of the right pier and in the left side of the left pier, should be tightened before testing is resumed. The gratings in all outlet units should be checked and tightened before they are placed in operation.

OUTLINE OF NEXT TEST

26. Alterations and repairs for the next test.

After a study and discussion of the results of the test of August 7, 8, and 9, it was concluded that certain alterations and repairs should be made to the outlet and a test performed to determine the opening of the 84-inch needle valve at which continuous and satisfactory operation would result. The repairs and alterations agreed upon were as follows:

(1) Install a pressure tap in the cover to the manhole to the transition elbow for attaching a pressure-vacuum gage to determine the pressure conditions at this point during operation of the valve at various openings.

(2) Clean and repaint the damaged area of paint on top of the tip of the needle valve.

(3) Clean and repaint the areas in the transition elbow from which the paint has been removed by cavitation.

(4) Repair the pitted areas in the wall of the anchor block immediately below the ends of the exit to the transition elbow.

(5) Chip the concrete in the pitted area near the joint 17' -9"

upstream from the draft tube piers where the patch had been torn out during the test of August 7, 8, and 9 and repatch the chipped area, eliminating any discontinuity in the concrete surface in this region.

(6) Grout the cracks and joints in the draft tube piers.

(7) Tighten the anchors to the two remaining gratings to the draft tube unwatering valves.

27. Test procedure.

With the alterations and repairs listed above, the test procedure is to be somewhat as follows.

The needle valve is to be opened to 40 percent and the outlet allowed to operate for 24 hours or until such time as there is indication that damage will or will not occur at this opening. The outlet is then to be unwatered and inspected and the conditions in the critical zones, including the surfaces of the needle valve, noted. Adequate photographic records are to be made also. If the operation at this opening proves satisfactory the valve opening is to be increased by increments of 5 percent until unsatisfactory conditions are encountered, the same procedure being followed as for the 40 percent opening. The air demand for each of the 18-inch vents is to be recorded for each valve opening.

Should conditions in the transition elbow prove to be critical at a smaller opening than those in the draft tube, it seems that the opening should be increased until unsatisfactory conditions are indicated in the draft tube or until the valve is fully open. If at the fully open position the transition elbow is found to be the only critical region and it is desired that the valves operate at full capacity steps should then be taken to correct the conditions of this part of the structure by one of the two methods mentioned in section 20 of this memorandum.

It is believed that my presence will not be required during the test and that interpretation of the results can be made through photographs sent to the Denver office, thus my departure for headquarters in Denver has been tentatively set for August 30.

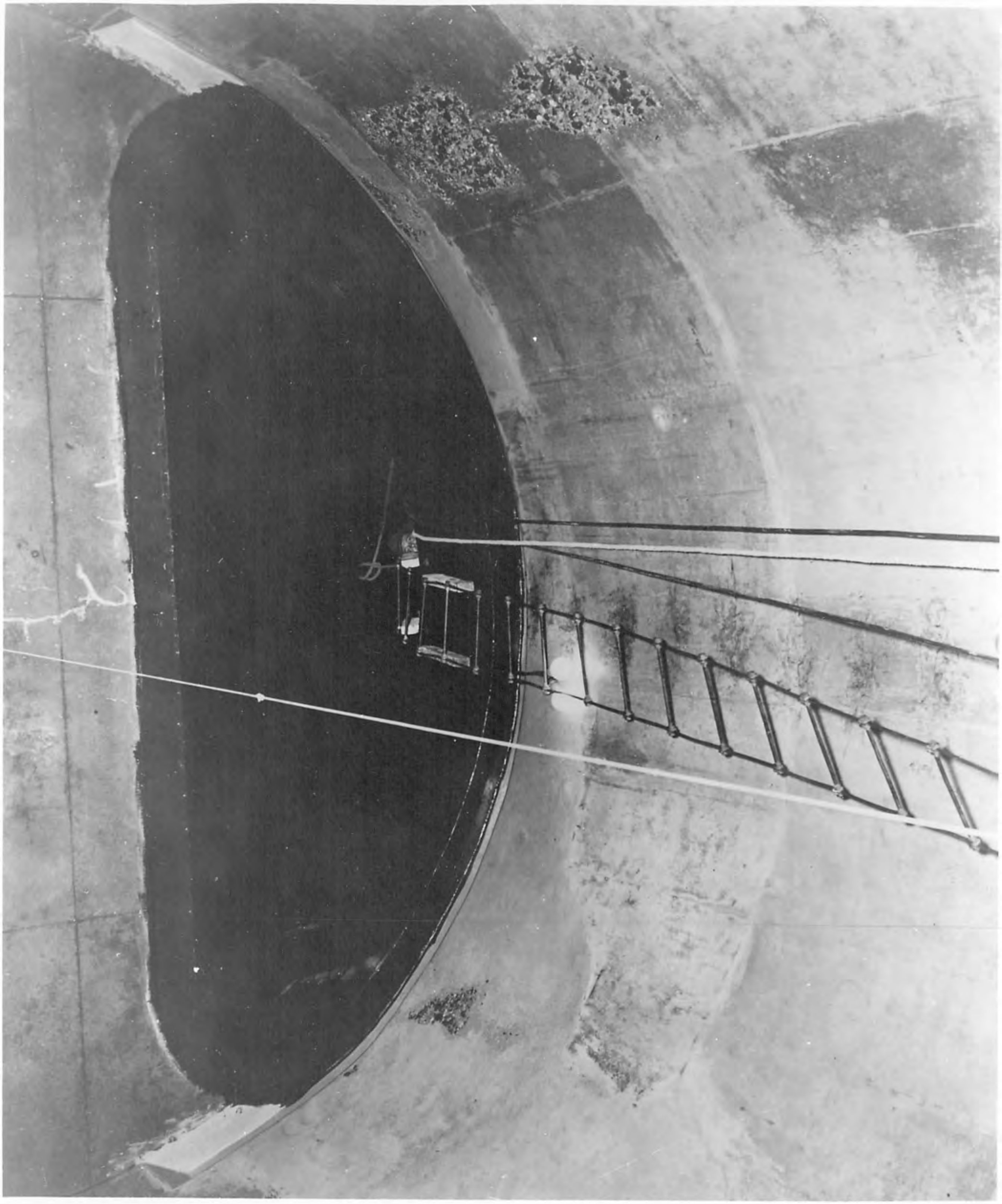
\- - -

J. W. Ball

cc-Denver office
Field Office
BAH
APN
JWB
Files

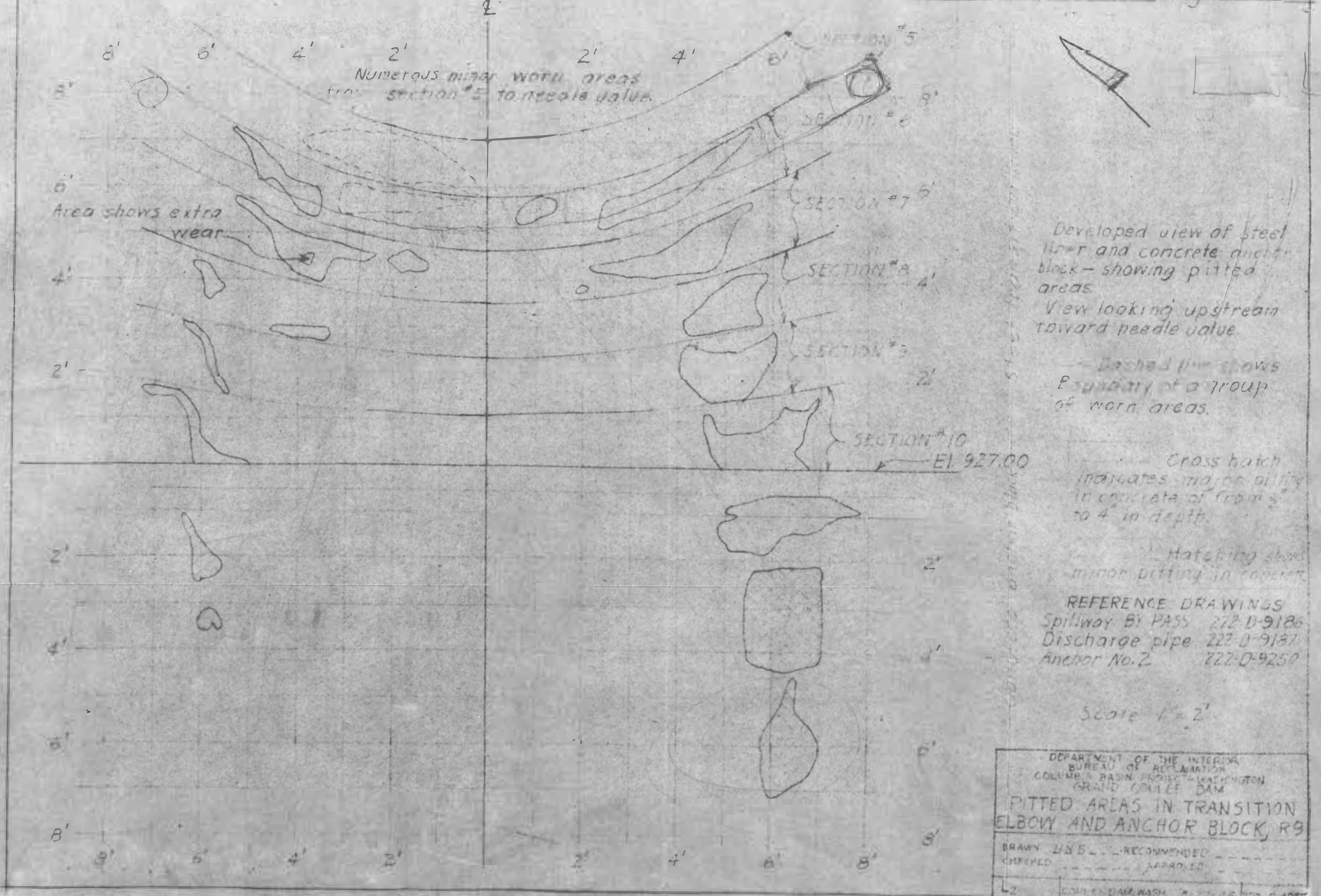
Figure 1

Photograph 4930-2, August 8, 1945: View from draft tube floor showing extent of cavitation in wall of anchor block at back of draft tube and near the recess from which a concrete patch had been torn during operation of the R-9 outlet for approximately 6 hours at full capacity on August 7, 1945.



Photograph 13247-3, August 10, 1945: View from floor of draft tube showing pitting by cavitation in the inner curve at both sides of the steel elbow and in the wall of the anchor block immediately below after operation of the R-9 outlet at full capacity for approximately 23 hours on August 7, 8, and 9, 1945.

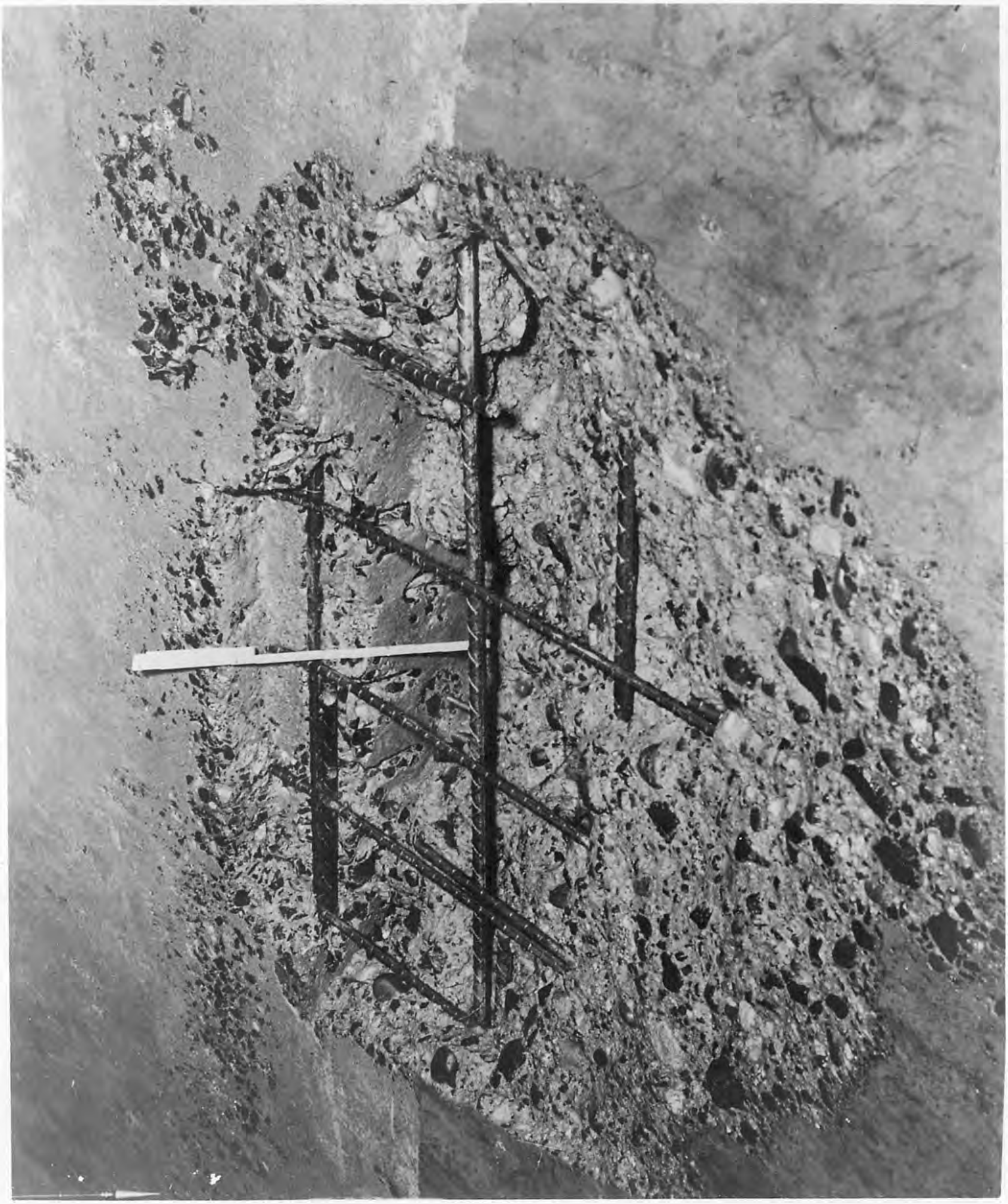
Figure 4



Numerous minor worn areas from section #5 to needle valve.
Area shows extra wear
SECTION #5
SECTION #6
SECTION #7
SECTION #8
SECTION #9
SECTION #10
El. 927.00
Developed view of steel liner and concrete anchor block – showing pitted areas.
View looking upstream toward needle valve.
Dashed line shows boundary of a group of worn areas.
Cross hatch indicates major pitting in concrete of from 3" to 4" in depth.
Hatching shows minor pitting in concrete
REFERENCE DRAWINGS
Spillway BY PASS 272-D-9186
Discharge pipe 222-D-9187
Anchor No. 2 222-D-9250
Scale 1" = 2'
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT – WASHINGTON
GRAND COULEE DAM
PITTED AREAS IN TRANSITION ELBOW AND ANCHOR BLOCK, R9
DRAWN
RECOMMENDED
CHECKED
APPROVED
COULEE DAM, WASH.
272-F-4257
J.W. Ball

Photograph 13246-3, August 10, 1945: View from draft tube floor showing extent of cavitation in wall of anchor block and in floor of draft tube in vicinity of recess from which patch was torn during first six hours of operation, after operation of the R-9 outlet for approximately 23 hours on August 7, 8, and 9, 1945. Plumb bob indicates centerline of 18-inch vent in top of anchor block.

Photograph 13242-3, August 9, 1945: View from draft tube floor showing pitting by cavitation in area near joint 17'-9" upstream from draft tube pier nose from which patch was torn, after operation of the R-9 outlet for approximately 23 hours at full capacity on August 7, 8 and 9, 1945.

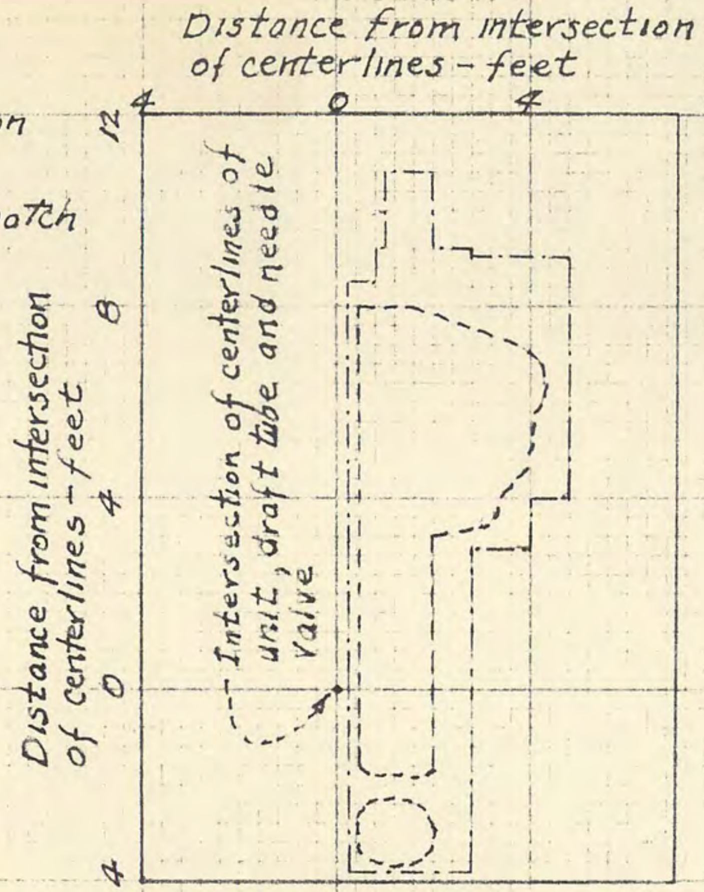


Photograph 13252-3, August 10, 1945: View from draft tube floor showing pitting by cavitation in area near construction joint 17'-9" upstream from draft tube pier nose from which patch was torn, after operation of the R-9 outlet for approximately 23 hours at full capacity on August 7, 8 and 9, 1945. Plumb bob at left indicates center of 18-inch vent pipe in top of anchor block.

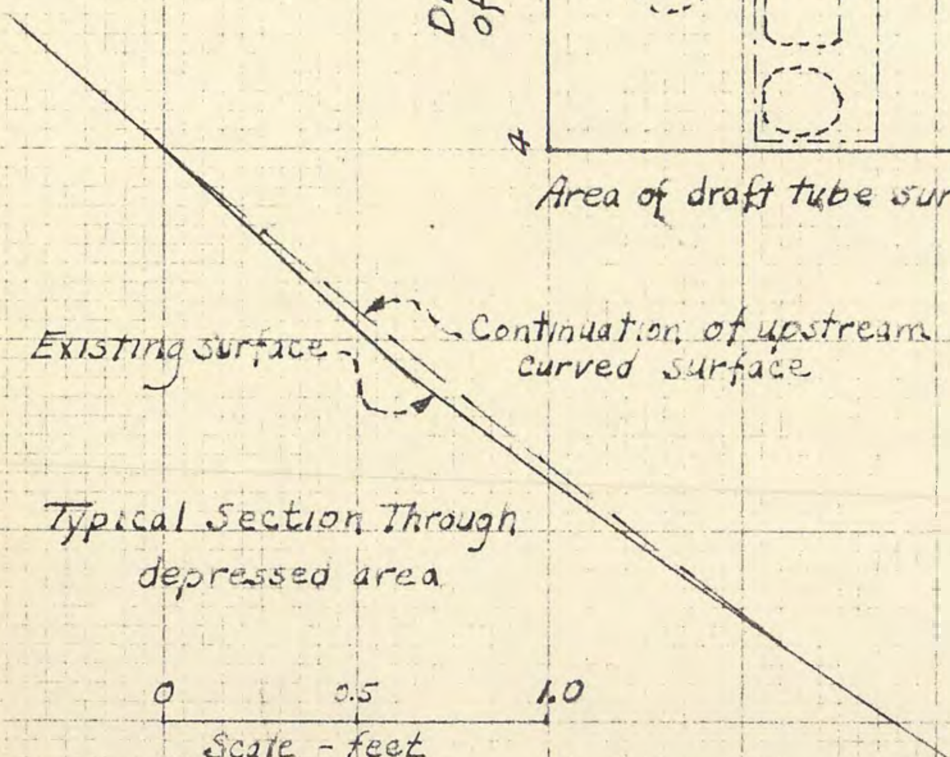
Figure 8

---Outline of depression
and pitted area

—·— Outline of new patch



Area of draft tube survey



Typical Section Through
depressed area

GRAND COULEE DAM
NEEDLE VALVE OUTLET,
Survey of Curved surface
at back of draft tube R-9
after test operations of
August 7, 8 and 9, 1945

8-27-45 J.W.B.

Photograph 13248-3, August 10, 1945: View from draft tube floor showing chipped edge in concrete adjacent to top of metal pier nose, left pier of draft tube R-9 outlet operated at full capacity for approximately 23 hours.

Photograph 13250-3, August 10, 1945: View from draft tube floor showing hole in right side of the right draft tube pier nose from which part of concrete is missing after operation of the R-9 outlet at full capacity for approximately 23 hours on August 7, 8 and 9, 1945.

Photograph 13249-3, August 10, 1945: View from draft tube floor showing recess from which grating to draft tube drain valves was torn during operation of the R-9 outlet at full capacity for approximately 23 hours on August 7, 8 and 9, 1945.