UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 189
TESTS ON 24-INCH HOLLOW-JET VALVE AT BOULDER DAM

379' Head.

By

FRED LOCHER

- - -

Denver, Colorado,
Nov. 29, 1945

HYD 148: 6" model test

HYD 189

UNITED STATES
DEPARTMENT OF THE INTERIOR
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Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
November 29, 1945

Laboratory Report No. 189
Hydraulic Laboratory

Compiled by: Fred Locher
Reviewed by: J. W. Ball

Subject: Tests on 24-inch hollow-jet valve at Boulder Dam.

1. Introduction. Tests conducted on a six-inch model of a hollow jet valve in the hydraulic laboratory at Denver, Colorado, and reported in hydraulic laboratory report No. 148 indicated that so far as it was possible to ascertain from the tests, the valve should perform satisfactorily at all heads and valve openings.

In the construction of the six-inch model all surfaces of the water passages were carefully machined to a predetermined contour. This was not possible in the prototype because, for structural reasons, it was desirable to cast the supporting vanes, the cylinder containing the needle and the outer shell in one piece. The arrangement made it practical to machine only the needle and that part of the inside of the outer shell upstream from the vanes (figure 1) leaving the remainder of the water passages in the form obtained from the mold.

The rough passages and the variation from the design contour, due to casting, caused some to question the possibility of local cavitational erosion occurring in the unmachined water passages. This possibility, combined with the fact that it was not possible to explore the pressures on the smaller 45 degree vanes in the six-inch model, brought about the decision to construct a 24-inch valve and test it with all of the head available on the test apparatus located in the Arizona valve house at Boulder Dam. The valve was designed for use at the Mancos Project after completion of the tests at Boulder Dam, but was of sufficient strength to withstand the higher head at Boulder.

During July and August of 1944 the drawings, specifications, and contracts were prepared for the purpose of obtaining the parts required for the fabrication of a 24-inch hollow-jet valve. Due to emergency conditions, it

was felt that no single contractor would bid on the entire job, so the invitations for bids were arranged such that any interested firm could bid on some part or parts of the valve. For the same reason, and to expedite the program, the machine work on the various parts was performed in the machine shops at Boulder Dam. The invitations for bids were mailed in September of 1944 to various companies throughout the region. The contracts were let during that and the following month with the latest delivery date being January 12, 1945, this date being applied to the castings of the valve body, the needle, the needle support, and the control stand.

Most of the material was delivered according to schedule and all of the contracted parts were in Boulder City by January 12, 1945, except the castings for the valve body, needle, needle support, and control stand. These, however, were cast and ready for inspection at the foundry. On January 15, 1945, the castings were inspected and accepted by an authorized Government inspector. It was not until February 13, 1945, that the castings were shipped from the foundry at Yakima, Washington. They arrived in Boulder City the latter part of March 1945. The machining of the valve covered the period from March 1945 to the middle of June 1945, at which time the Director of Power informed the Denver office that the valve was ready for testing.

The writer arrived in Boulder City June 25, 1945, at which time the valve was inspected and additional work requested on the unmachined surfaces of the valve body. This work was performed and the valve was installed ready for testing at 1:30 p.m., June 30, 1945. The tests were in progress until 1:40 p.m., July 9, 1945, at which time the Regional Director requested that testing be discontinued because of the urgent need of conserving water for power. At the time the tests were discontinued, the valve had been operated a total of 47 hours at various openings and had discharged a total of approximately 455 acre-feet of reservoir storage. The valve was operated an additional 2-1/2 hours while photographs were made of the jet and for a demonstration for two engineers from the Portland, Oregon District Engineer's Office.

2. <u>The mechanical condition of the valve before testing.</u> An inspection of the valve before it was installed revealed that the experimental metco liner (a process where tobin bronze was sprayed on the cast iron) on the valve

body did not bond properly at the upstream and downstream ends of the liner. There was no visible separation of the two metals, but the absence of bond was detected by tapping the metalized surface with a hammer. In addition, the liner would not finish to a polished surface, and the material had a porous texture which was not conducive to easy sliding of one metal surface on the other where water was the only lubricant.

The cast surfaces of the valve body were quite rough. There were numerous slag pockets and evidence of wash in the mold due to pouring of the metal (figures 2 and 3). Other areas of the casting showed roughness due to careless handling of the molds. In the unmachined areas of the casting, a certain amount of the roughness was eliminated by hand grinding. However, it was not possible to obtain a smooth surface without excessive grinding and destroying the designed contour of the valve. The machined surfaces of the valve body finished down to sound metal except the region at the upstream flange where the slag pockets were quite deep (figure 4). Figures 5 and 6 show the character of the junction of the vanes with the valve body before and after grinding. The abrupt shoulder at the upstream end of the splitter was the result of machining. This condition (figure 4) may be expected in future valves, and it should be specified that this part should be feathered to the valve contour as shown in figure 6.

The bronze seat ring on the valve body was not satisfactory. The welding of the bronze seat ring to the valve body caused the adjacent cast iron to flame harden and made it very difficult to machine the body seat. On this particular valve, the finishing work on the seat and the adjacent area was done by hand. The workmanship at the foundry of welding the seat in place was of an inferior nature. There was leakage at the junction between the bronze and the cast-iron body. There were also porous areas in the bronze which permitted passage of the water through the seat. An attempt was made to fill the porous areas with silver solder, but this was not entirely successful. A good bond was not obtained between the solder and the bronze, and in addition the solder was too soft to withstand the pressure due to seating the needle.

The metal in the bronze seat ring of the needle was also porous and resulted in leakage through the ring. Silver solder was placed in the porous

areas, but for reasons previously explained it was not satisfactory.

3. Thrust on the needle. It was anticipated that the larger diameter holes comprising the balancing ports would cause a different pressure in the balancing chamber than would be indicated by a piezometer located in a position representing the centerline of the balancing port, so pressure measurements were taken on the needle and inside of the balancing chamber to check the magnitude of the unbalanced thrust on the needle. The pressure factors obtained on the needle of the 24-inch valve were practically the same as those obtained in previous tests on the 6-inch model. However, the pressure inside of the balancing chamber was higher than was indicated by tests on the 6-inch model. The pressure in the balancing chamber of the 24-inch valve was equal to that which would have occurred at a piezometer located on a radius smaller by three-fourths of the radius of the balancing port opening than that which would have occurred at a piezometer located on the actual radius from the center of the valve to the center line of the ports.

The significance of this was that, while the thrust on the needle was essentially the same as was determined from the six-inch model, the balancing force had increased considerably, with the result that instead of obtaining a maximum unbalanced thrust of 9,000 pounds as anticipated in the design, the force was actually 10,700 pounds (figure 7).

Instead of the value of the maximum unbalanced force being approximately equal at 20 and 100 percent of full opening, the thrust at 20 percent was approximately 1.48 times that at 100 percent as shown on figure 8, which shows the thrust value as reduced to that for a constant one-foot head on a 12-inch diameter valve. When the reduction in head between the closed and open positions due to friction losses in the supply line was considered, the ratio increased to 2.48 as shown in figure 7. This indicated that the fixed radius of 0.4050, based on a unit inlet diameter, to the center line of the balancing port circle was too small. In addition, it was apparent that this radius should be varied according to the particular valve installation to compensate for the difference in thrust resulting from the variation in available head between the closed and open positions. The unbalanced thrust on the needle at the Boulder installation can be understood more clearly by the following computation. From the curves of figure 8, the maximum unbalance occurs at

20 percent of full opening and amounts to 8.1 pounds per foot of head on a 12-inch valve. Since the total head on the valve at 20 percent of opening was 330.89 feet of water, and the transfer equation for thrust was $T = n^2 H t$ where T = the thrust, n = the diameter of the valve in feet, H = total head on the valve, and t = unbalanced thrust selected from figure 8, the total unbalanced thrust on the 24" valve at 20 percent opening was:

20% 330.89

$$T = 4 \times 330.89 \times 8.1 = 10{,}720 \text{ pounds.}$$

At 100 percent opening, the total head available at the valve was 196.6 feet of water, and the unbalanced thrust was equal to 4 X 196.6 X 5.5 = 4,325 pounds. If there had been no friction losses in the conduit leading to the valve, the values of the thrust would have been 11,300 at 20 percent, and 7,680 at 100 percent opening.

100% 196.6

To adjust the unbalanced thrust, which was upset by the diameter of the balancing port, such that the values at 20 and 100 percent of full opening were equal with a constant head on the valve, required changing the unit diameter to the center line of the balancing port circle from 0.8100 to 0.8278, or from 19.44 inches to 19.87 inches on the 24-inch valve. As there usually is an appreciable difference in the available head at the valve between the closed and open positions, another correction in the diameter of the balancing port circle was necessary to keep the magnitude of the unbalanced force the same at 20 to 100 percent of opening. This correction varies with the ratio of total head at the valve when it is fully open to the total head on the valve when it is closed. This is shown on figure 9 where the variation in diameter of the center line of the balancing port circle has been plotted against head ratio at closed and open position. The diameters are given in unit dimensions.

If only one valve is used on a conduit, the ratio of head at the valve wide open to the reservoir head should be used in determining the location of the balancing ports. If several valves are connected by a manifold arrangement to a larger conduit, the head ratio should be determined for the valve having the least conduit loss with the remaining valves closed. The radius thus obtained from figure 9 can be used for all of the valves of the particular installation. The thrust will not be of the same magnitude at 20 and 100

percent because of the variation in conduit losses due to varied operation of the valves. However, the magnitude of the maximum unbalanced thrust will not exceed 0.125 WHA where W = 62.4, H = reservoir head above the center line of the valves, and A = effective area of the balancing chamber. If the above procedure is followed for determining the diameter of the balancing port circle, the magnitude of the unbalanced thrust will always be less than 0.125 WHA which is the maximum unbalanced thrust for an installation void of head losses. The curve of figure 9 has been corrected for the increase in pressure in the balancing chamber resulting from using port holes having a unit diameter of 0.0208.

The 24-inch valve used in the tests at Boulder Dam will be installed permanently at Jackson Gulch Dam where the estimated maximum head ratio with one valve operating wide open was 0.606. This gave a new diameter of 20.09 inches for the center line of the balancing port circle as compared to 19.44 inches in the initial design. This charge will be made on the valve before it is installed at Jackson Gulch. The unbalanced thrust for the Boulder test installation with the new location of the balancing ports is shown on figure 7. The curve shows unequal magnitudes of unbalance at 20 and 100 percent of full opening and is due to higher losses in the Boulder installation than was anticipated to occur at Jackson Gulch.

4. Pressure measurements on the valve. Piezometers were installed on the valve body and needle as shown on figures 10 and 11. Additional piezometers were placed on the large vanes, and one was located in the air chamber downstream of the needle. Pressures were taken at each ten percent of valve opening. The results for the needle and the valve body are shown on figures 10 and 11 along with pressures obtained from the six-inch model with piezometers in homologous locations.

A satisfactory agreement between the piezometric pressure on the needles of the 6 and 24-inch valves was obtained, with the exception of piezometer 24 when the needle was near the closed position, and piezometer 17, throughout the full needle travel. The deviation at piezometer 24 was caused by the inability to accurately machine the valve body to the designed contour, which difficulty will be explained later. The inaccuracy of the body contour did not reflect on the pressure at the spring point of the needle until the valve

approached the closed position, at which point the decreased curvature from the design body contour caused an increase in pressure at piezometer 24. The variation at piezometer 17 was due to a slot in the needle-nut which was directly upstream and in line with the piezometer.

In the construction of the valve a tobin bronze seat was welded into a groove of the valve body. As a result, considerable flame hardening occurred in the cast iron which made this area difficult to machine. Several carbaloy tools were broken in the attempt to cut the flame-hardened surface, and the final finishing had to be done by hand. Consequently, it was not possible to obtain the true contour of the valve at this point. In addition, the machined surface was feathered to fit the rough casting just upstream of the splitters causing a further deviation from the contour. While this did not affect the over-all performance of the valve, the piezometric pressures obtained on the body were not in agreement with those on the six-inch model (figure 11). However, in view of the discrepancies an agreement was not expected.

Piezometer 8 on the valve body was negative for small openings. This was due to a local irregularity in the unmachined part of the casting. Ordinarily, with a smooth surface all pressures in this region would be positive.

The piezometer located in the air space immediately upstream of the vanes showed a maximum negative pressure of 1.22 feet of water when the valve was fully open and the total head on the valve was 196.6 feet of water.

The piezometers located on the large vanes showed negative pressures at 10 and 20 percent of full opening. The maximum negative pressure was 2.78 feet of water at 20 percent opening where the total head was 330 feet of water. These negative pressures were probably the result of local irregularities in the rough casting and have no particular significance.

5. Cavitation Tests. It was realized at the time that the laboratory tests were being conducted that it would not be possible to obtain the quality of surface finish of the water passages in the prototype as were obtained in the six-inch model.

For structural reasons, the ribs, inner shell, and outside shell forming the "body" of the valve were cast in one piece. This made it impractical to machine the vanes or the downstream part of the water passages on the body.

The character of the surface that would be obtained in the prototype, due to irregularities in the molds, raised the question of the possibility of local cavitation resulting from these irregularities and other roughness inherent in the casting process. It was mainly for this reason that the 24-inch valve was tested under high heads at Boulder Dam.

When cavitation exists in a piece of apparatus it is usually accompanied by vibration and a sharp metallic sound, especially if the action is taking place against a metal surface. If the action is severe, the staccato metallic sounds occur with extreme rapidity, and evidence of the resulting pitting will be apparent after only a few hours of operation. When the action of cavitation is less severe, or what might be called mild, it would take a considerable period of operating before the destructive effects would be noticeable on iron or steel. Vibration under these circumstances is usually nonexistant or of minor importance.

The 24-inch hollow-jet valve was operated intermittently under various heads between 349 and 197 feet of water and at various openings for approximately 30 hours. During that time there was no evidence of vibration, no staccato metallic sounds from the valve, nor any indications of pitting due to cavitation on the valve. 349? 197?

As has been mentioned previously, the shortage of water prevented an extended period of operation to determine if cavitation was present in the so-called mild form, so an accelerated test was made whereby the surface of the water passages were given a coat of glyptal and the valve operated an additional 16 hours. During this time the valve setting was changed, and the head on the valve varied with the friction losses in the conduit. At the conclusion of the test the valve was dismantled and examined closely for any evidence of erosion of the paint. The examination did not disclose any eroded or worn spots (figures 12 and 13). From this it was concluded that local cavitation due to surface irregularities was not present in the valve under the heads available for the test, for had there been cavitational erosion present, it would have damaged the paint within a few hours of operation.

The piezometric pressures were positive or so nearly positive that the general contour of the valve can be considered satisfactory. This is the

same conclusion that was drawn from the tests on the six-inch model.

6. Character of the jet. The jet from the 24-inch hollow-jet valve was different from that shown in laboratory report Hyd. 148 for the six-inch model in that there was no marked division of the jet into four parts due to the large vanes in the water passage, except for a distance of about 12 inches downstream from the valve. In this region the jet was divided and allowed a sufficient amount of air to enter for aeration. There was an expansion of the jet (figure 14) which was not noticeable in the six-inch model and was probably due to insufflation of air.

The jet, in general, maintained its shape for the full trajectory (figures 15 and 16) shedding a limited amount of spray over the entire range of travel. This was not objectionable and is characteristic of any jet of water traveling through the air at a high velocity.

7. The coefficient of discharge. During the testing a check was made on the coefficient of discharge. The reducer from the 24-inch to 20-inch conduit about 75 feet upstream from the valve had been carefully calibrated during tests of the 20-inch Shasta tube valve. The reducer was calibrated for discharge against difference in pressure for flows up to 200 second-feet. As the valve discharged 245 second-feet at full opening, it was not possible to check the coefficient at 100 percent of full value travel. However, a check was made at each ten percent of opening up to and including 70 percent. The results are shown on figure 10. When the valve approached the wide open position, the rating station indicated a slightly higher coefficient than was obtained with the six-inch model. Due to the higher value of Reynolds number, this was expected, and it appears that a coefficient of 0.700 for the larger valves is a more representative value than the 0.694 determined from the six-inch model.

8. The mechanical condition of the valve after the tests. A careful inspection of the Metco process liner in the valve body showed additional areas where the bond between the two metals was defective. Before installation and testing, only a narrow band at the upstream and downstream end gave any evidence of improper bond. After testing, other areas near the center of the liner emitted a hollow sound when tapped lightly with a hammer. The surface appeared more porous than before testing. However, this was probably the

result of the washing from the pores of the fine cuttings deposited therein during machining. The porosity of the liner is shown on figure 17.

The spray metal liner was a test piece only and was used to determine if a satisfactory surface could be obtained by the use of the Metco process. Its use in the hollow jet valves is not recommended, and it would be advisable to replace it with the bronze casting which was purchased at the time the body castings were made.

Figures 18 and 19 show the condition of the needle before and after testing. A considerable amount of corrosion due to a chemical action has occurred. It is believed that this surface as well as other exposed iron surfaces should be painted and kept painted with a good grade of wear-resisting paint to preserve the valve.

Other changes recommended on the 24-inch valve involve (1) replacing the bronze seat ring and (2) replacing and revising the body seat from that shown on figure 1 to that of figure 20. The bronze seat ring was porous and leakage through the metal occurred.

For future valves some investigating should be done to reduce the flame hardening at the junction of the weld material with the parent metal. A combination of a low fusing alloy against the cast iron with a 25-12 stainless weld for the actual seat might solve the flame hardening problem as well as produce a machinable seat.

9. Tests after Mechanical Revisions. In accordance with the recommendations of this report, the valve seat was altered as shown on figure 20, the Metco process liner was replaced with a cast bronze liner, and the diameter of the balancing port circle was increased to 20-1/8 inches. This additional work was completed about September 16, 1945, and the valve was placed on the test line to determine the suitability of the corrective measures.

It was found (1) that the insertion of the cast bronze liner in the valve body eliminated the tendency of the needle to bind, (2) that the combination ferro-weld and 25-12 stainless steel seat ring on the valve body was satisfactory, and (3) that the unbalanced thrust was more nearly equal to 20 and 100 percent of full valve travel with the new balancing port location.

The combination ferro-weld and stainless steel valve body seat was used in the 24-inch valve, because the initial groove for the bronze seat was 3/8 inch deep and would have required an excessive amount of stainless steel to fill the groove. It was also felt that the ferro-weld would reduce the amount of flame hardening in the cast iron. The body seats on future valves are to be constructed of K monel 3/16-inch thick and welded in place. Recent tests have shown no appreciable hardening of the cast iron at the weld, and it is believed that this type of seat will be machinable and provide a satisfactory seating area.

At the conclusion of the tests in September of 1945, it did not appear that any further mechanical improvements in the valve were necessary, although it was generally agreed that at some future date a scheme should be developed for eliminating the unbalanced thrust.

10. Conclusions.

a. While it is generally accepted that model and prototype pressures should agree very closely, the results of the pressure measurements on the valve have served to establish further proof of this concept. This relationship will exist if careful measurements are made in both the model and the prototype and if the two structures are exactly similar. Under certain conditions, a variation of a few thousandths of an inch in the contour of the water passage will cause a noticeable difference in pressure.

b. The diameter of the balancing port circle of the 24-inch valve should be changed from 19-7/16 inches to 20-1/8 inches to equalize the magnitude of the maximum unbalanced thrust at the Jackson Gulch installation.

c. The diameter of the balancing port circle should be established from figure 8 and will vary with the particular installation and between valves of identical size.

d. The jet emitting from the valve remained intact for the full trajectory. There was no undue raveling or evidence of dispersion at any opening.

e. The coefficient of discharge at full open position can be assumed to be 0.70 in view of the fact that measurements indicated a slightly higher value than was obtained from the six-inch model.

f. There was no evidence of cavitation in the valve nor was there any appreciable amount of vibration.

g. Care must be exercised in obtaining smooth surfaces in the water passages of the unmachined portion of the hollow-jet valve. This will be necessary to prevent the possibility of local cavitation when the valve is used with heads higher than the test heads at Boulder.

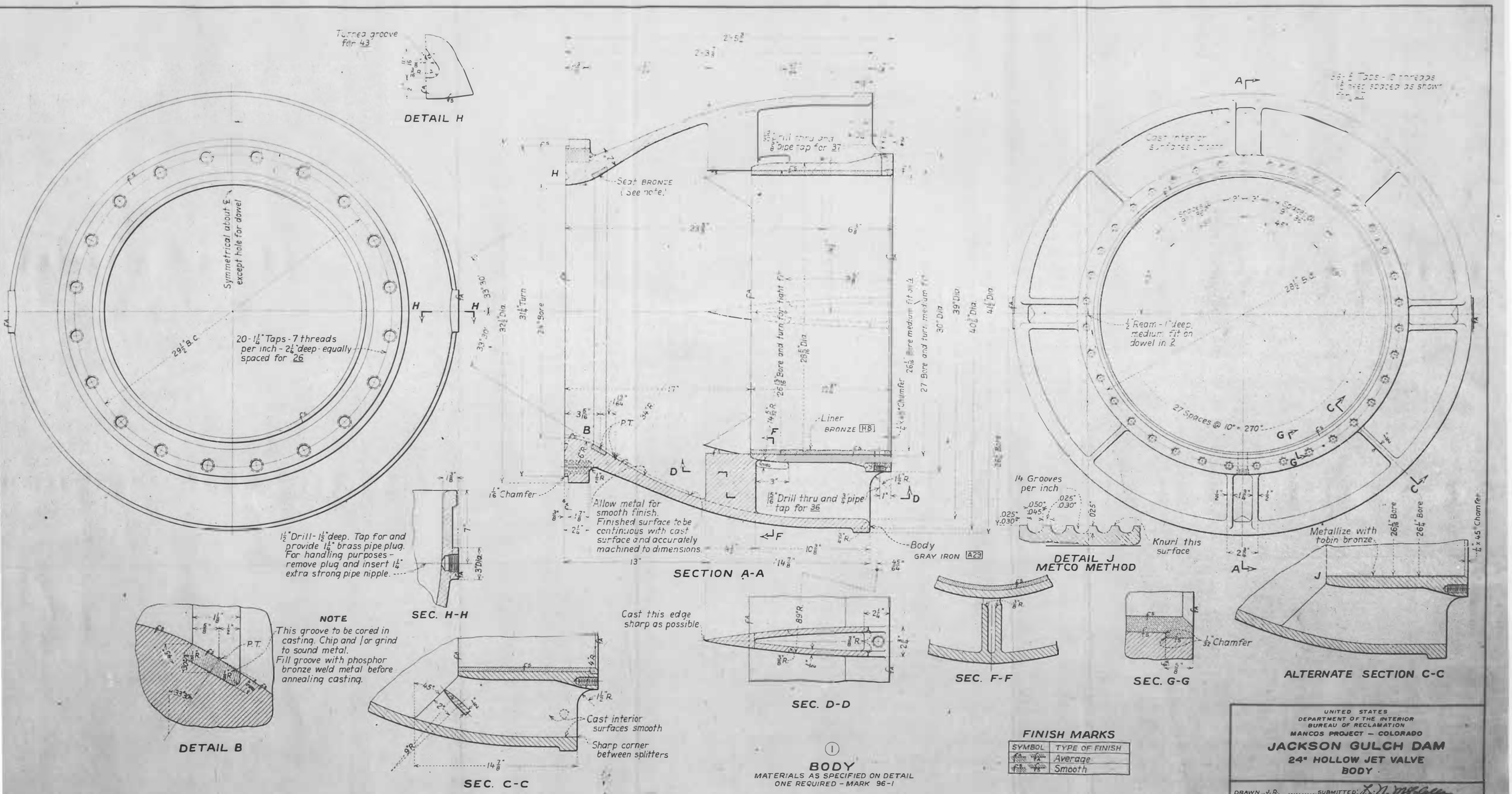
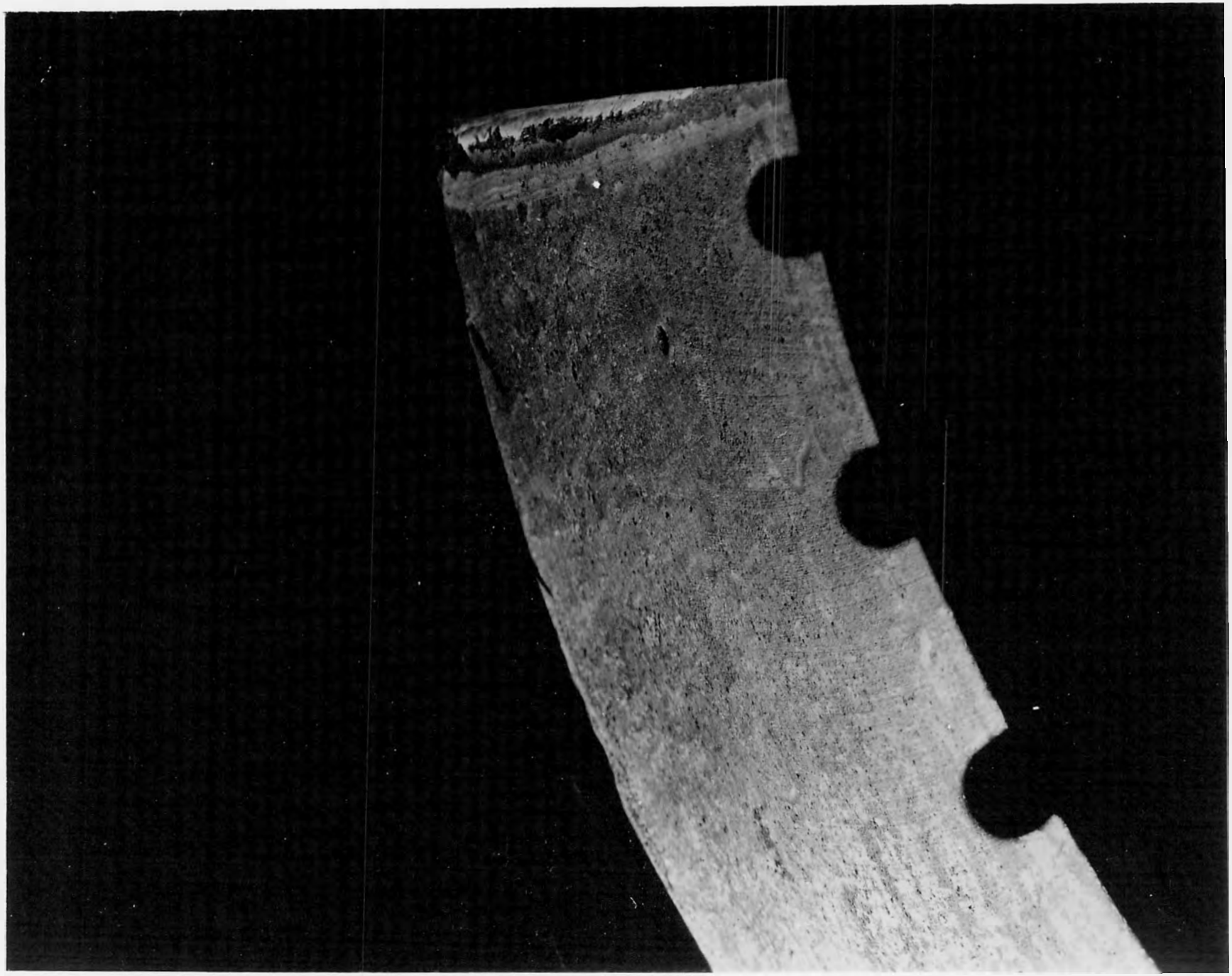

Turned groove for 43
DETAIL H
Symmetrical about ℄ except hole for dowel
20-1¼" Taps - 7 threads per inch - 2¼" deep - equally spaced for 26
29½" B.C.
33°30'
32½" Dia
31¼" Turn
24" Bore
1½" Drill - 1½" deep. Tap for and provide 1¼" brass pipe plug. For handling purposes - remove plug and insert 1¼" extra strong pipe nipple.
SEC. H-H
Seat BRONZE (See note.)
Drill thru and ⅞" pipe tap for 37
Liner BRONZE H8
26 13/16" Bore and turn for light fit
28 5/16" Dia
26¼" Bore medium fit on 4
27" Bore and turn medium fit
30" Dia
39" Dia
40⅜" Dia
41½" Dia
1/16" Chamfer
Allow metal for smooth finish. Finished surface to be continuous with cast surface and accurately machined to dimensions.
15/16" Drill thru and ¾" pipe tap for 36
Body GRAY IRON A29
SECTION A-A
Cast interior surfaces smooth
28½" B.C.
½" Ream - 1" deep medium fit on dowel in 2
27 Spaces @ 10° = 270°
14 Grooves per inch
DETAIL J METCO METHOD
Knurl this surface
Metallize with tobin bronze.
26⅛" Bore
26¼" Bore
¼" x 45° Chamfer
ALTERNATE SECTION C-C
NOTE
This groove to be cored in casting. Chip and/or grind to sound metal. Fill groove with phosphor bronze weld metal before annealing casting.
DETAIL B
Cast this edge sharp as possible
SEC. D-D
SEC. F-F
SEC. G-G
1/32" Chamfer
Cast interior surfaces smooth
Sharp corner between splitters
SEC. C-C
FINISH MARKS
SYMBOL | TYPE OF FINISH
Average
Smooth
1
BODY
MATERIALS AS SPECIFIED ON DETAIL
ONE REQUIRED - MARK 96-1
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MANCOS PROJECT — COLORADO
JACKSON GULCH DAM
24" HOLLOW JET VALVE
BODY
DRAWN J.R.
SUBMITTED: L.N. McClure
TRACED A.E.L.
RECOMMENDED
CHECKED K.H.B.
APPROVED
DENVER, COLORADO, JULY 17, 1946
SHEET 2 of 7
341-D-97

FIGURE 2

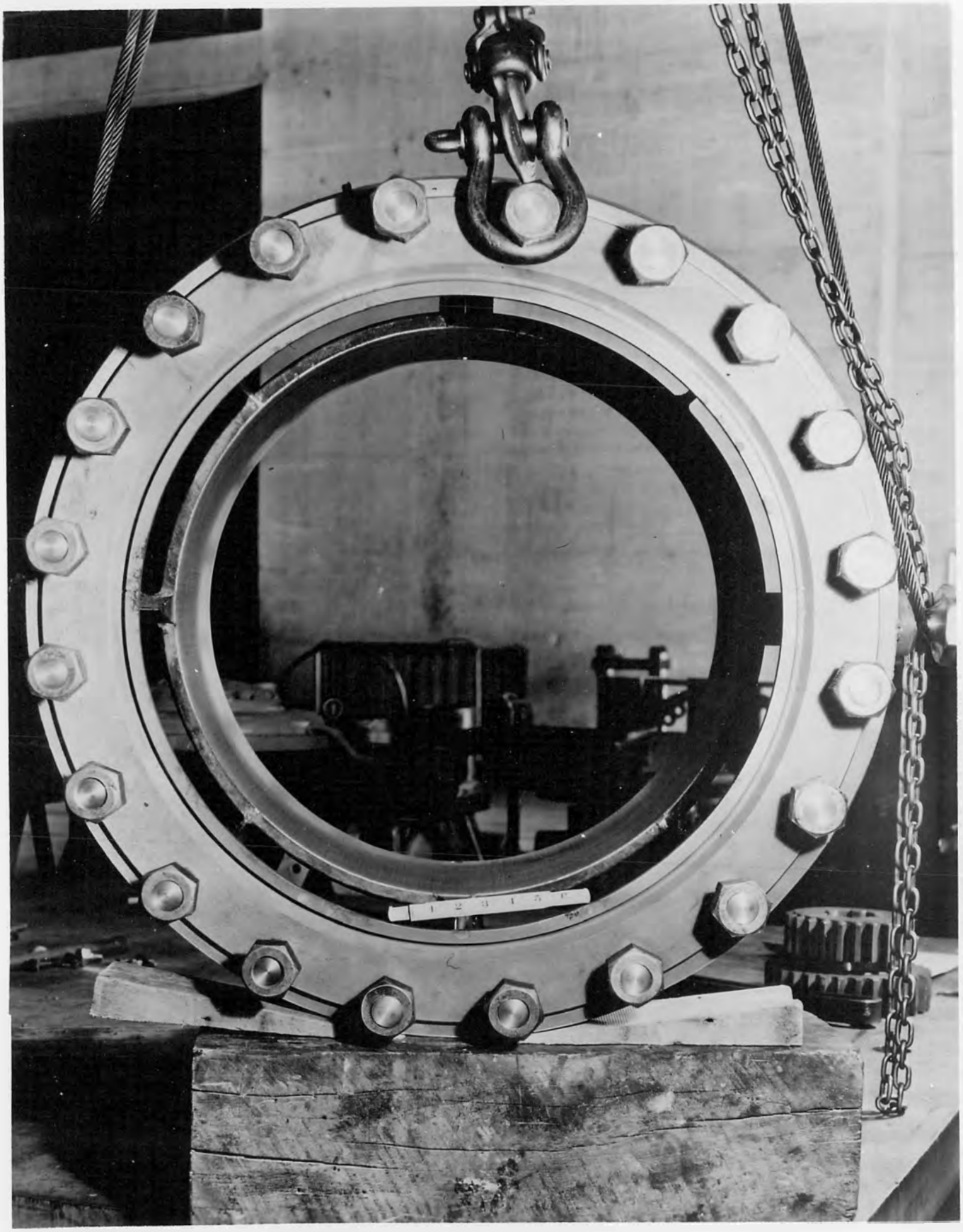
DOWNSTREAM END OF VALVE BEFORE TESTING-CHARACTER OF UNMACHINED SURFACES



CLOSEUP VIEW OF UNMACHINED SURFACE BEFORE TESTING

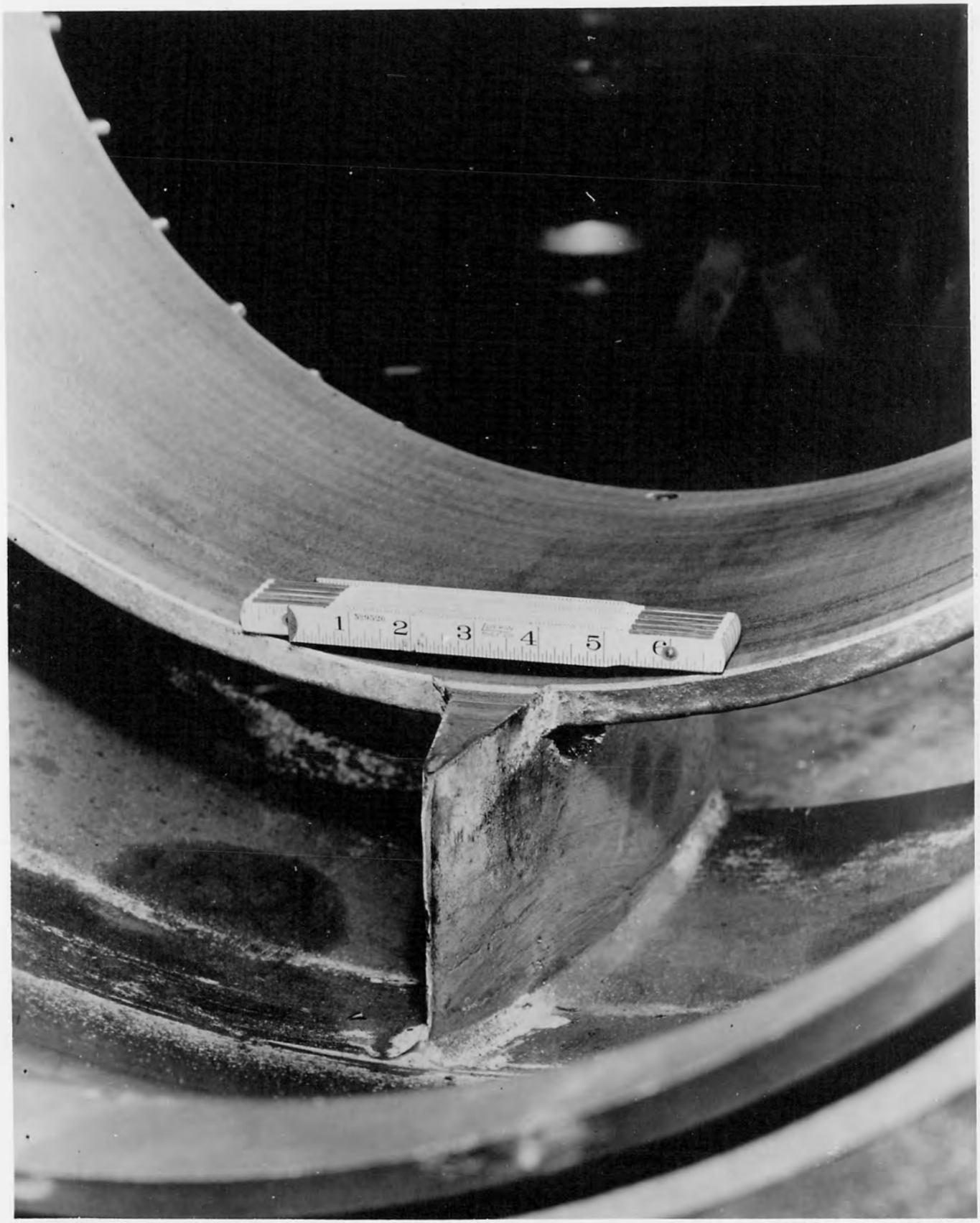
FIGURE 3

FIGURE 4



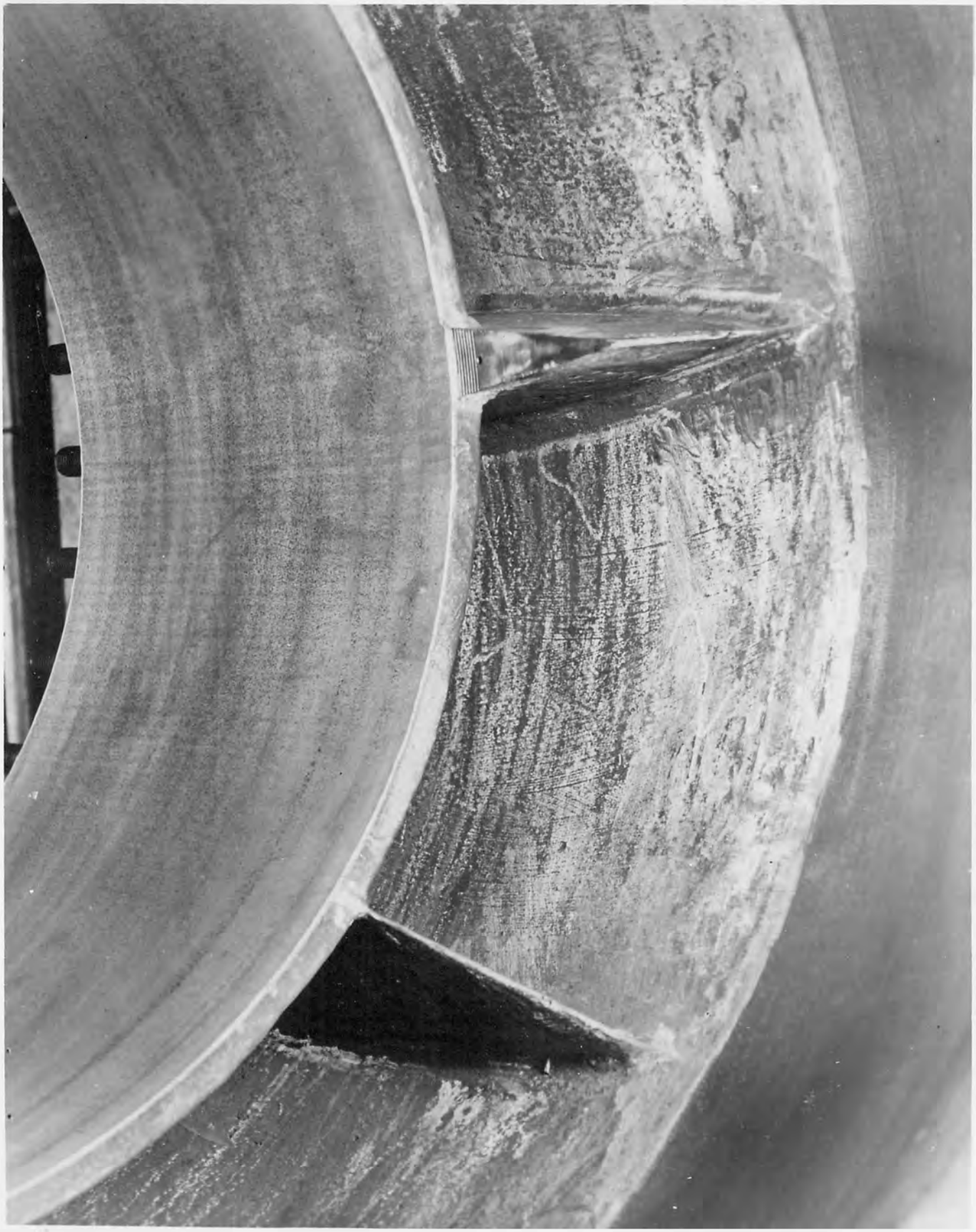
UPSTREAM END OF VALVE SHOWING SLAG POCKETS
IN FINISHED SURFACE OF FLANGE

FIGURE 5

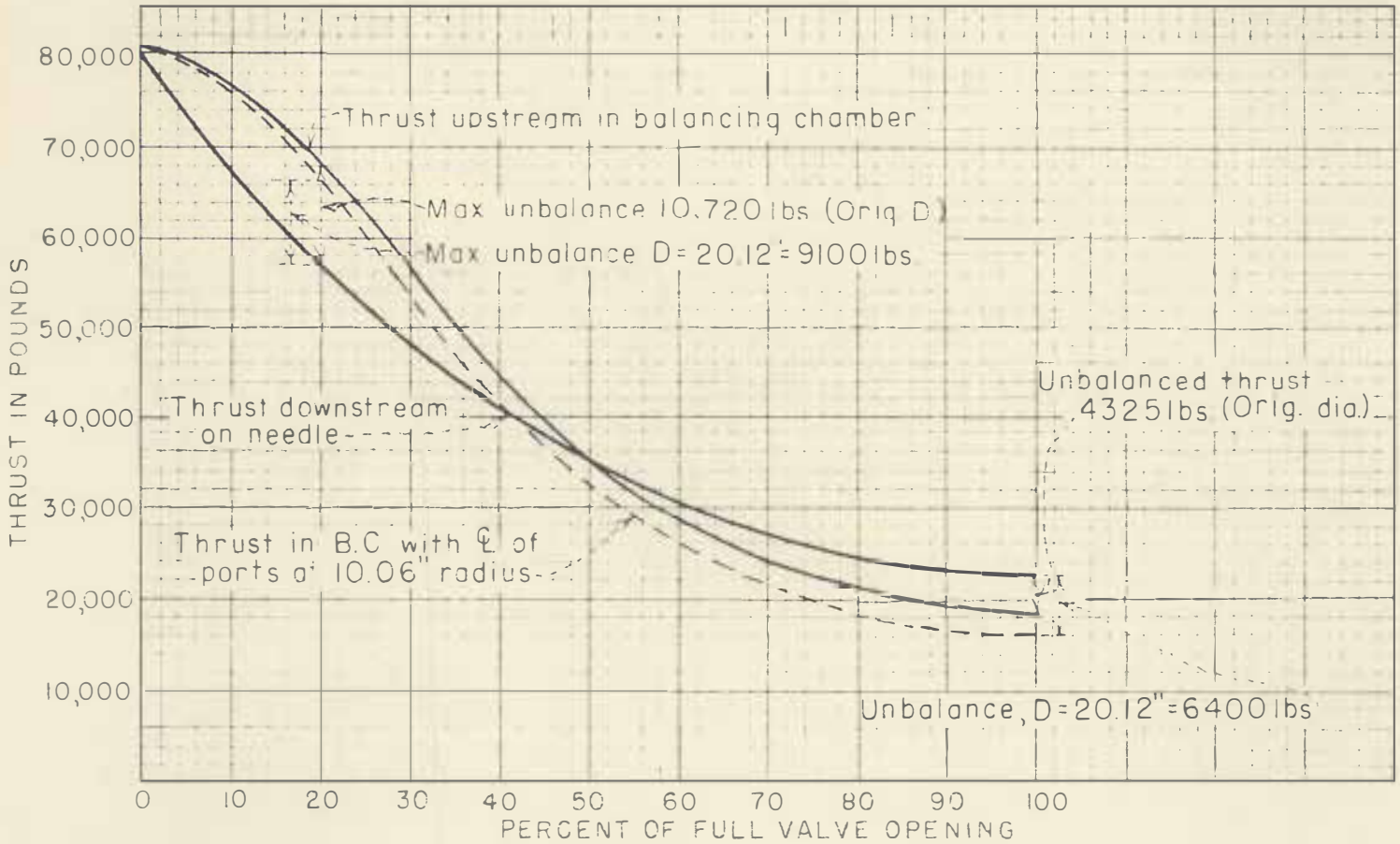


UPSTREAM END OF LARGE SPLITTER SHOWING JUNCTION OF SPLITTER WITH BODY BEFORE HAND FINISHING

FIGURE 6



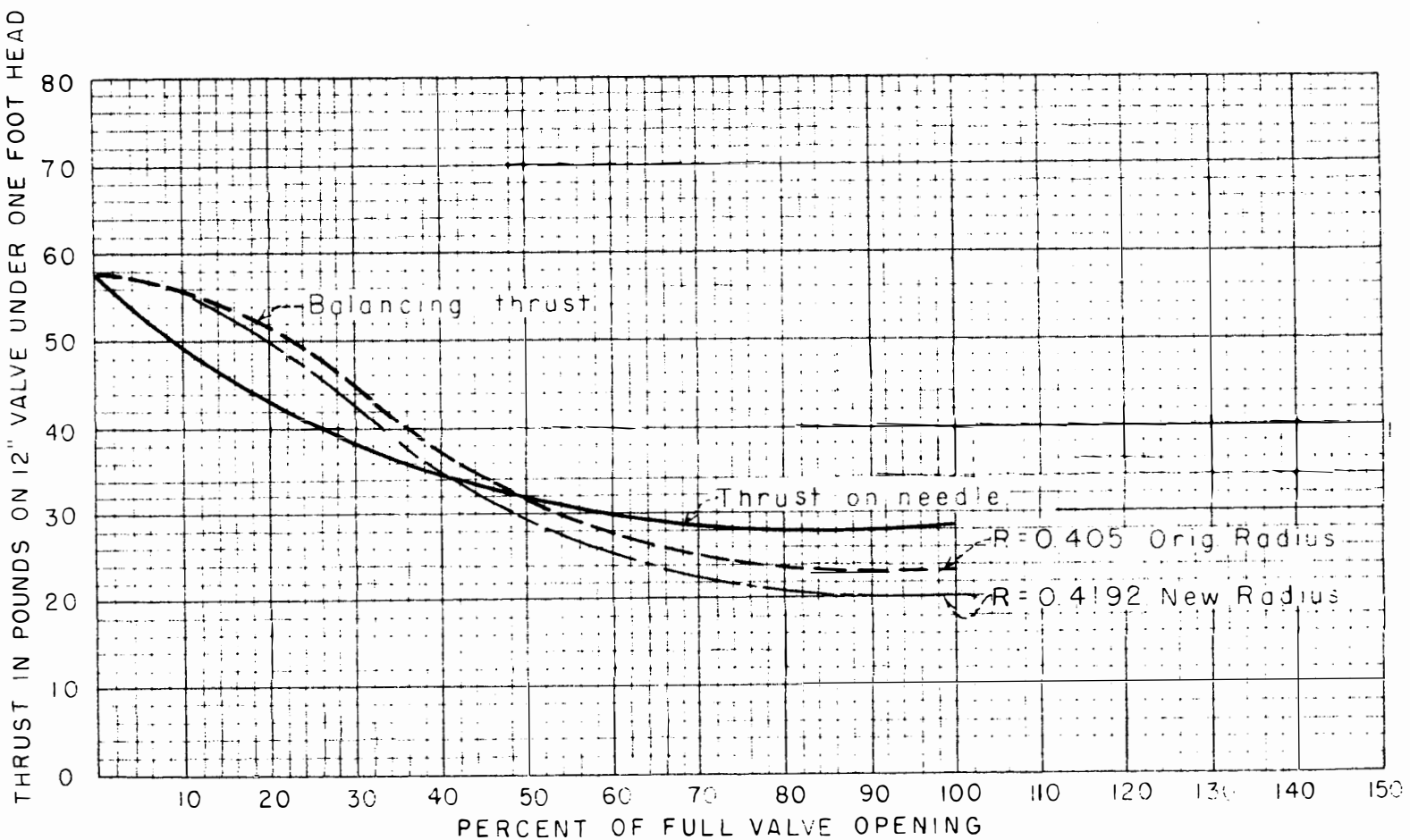
JUNCTION OF SPLITTERS WITH VALVE BODY AFTER HAND FINISHING



UNBALANCED THRUST

24 INCH HOLLOW JET VALVE TESTS
BOULDER DAM INSTALLATION

7-27-45



UNBALANCED THRUST
CONSTANT HEAD ONE FOOT
ON
12" DIA VALVE
8-1-45

FIGURE 8

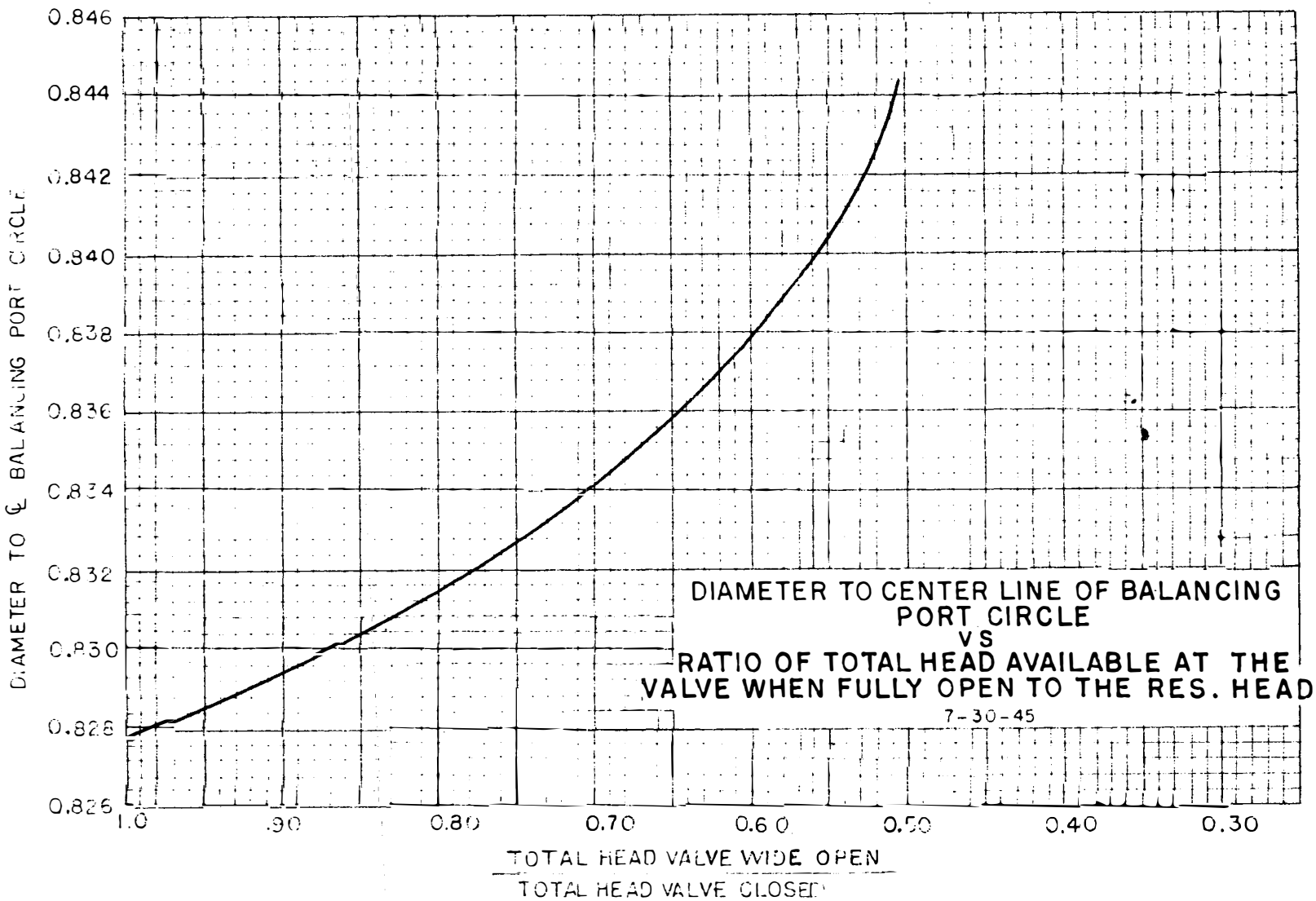
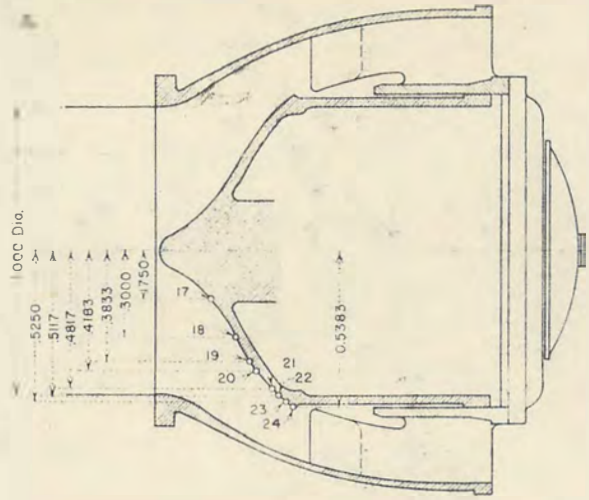

DIAMETER TO CENTER LINE OF BALANCING PORT CIRCLE
VS
RATIO OF TOTAL HEAD AVAILABLE AT THE VALVE WHEN FULLY OPEN TO THE RES. HEAD
7-30-45
DIAMETER TO ℄ BALANCING PORT CIRCLE
0.846
0.844
0.842
0.840
0.838
0.836
0.834
0.832
0.830
0.828
0.826
1.0
.90
0.80
0.70
0.60
0.50
0.40
0.30
TOTAL HEAD VALVE WIDE OPEN
TOTAL HEAD VALVE CLOSED

FIGURE 9

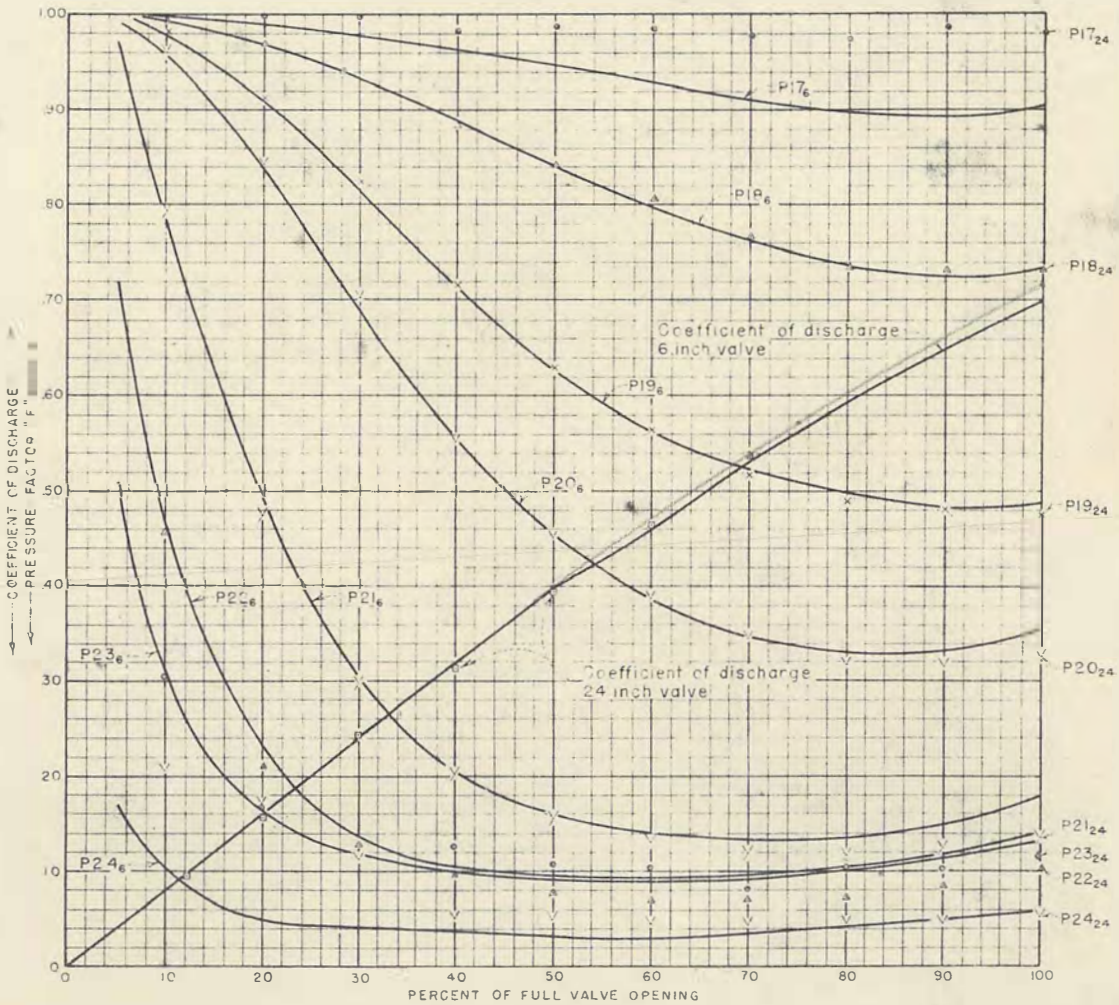


SECTION THROUGH VALVE

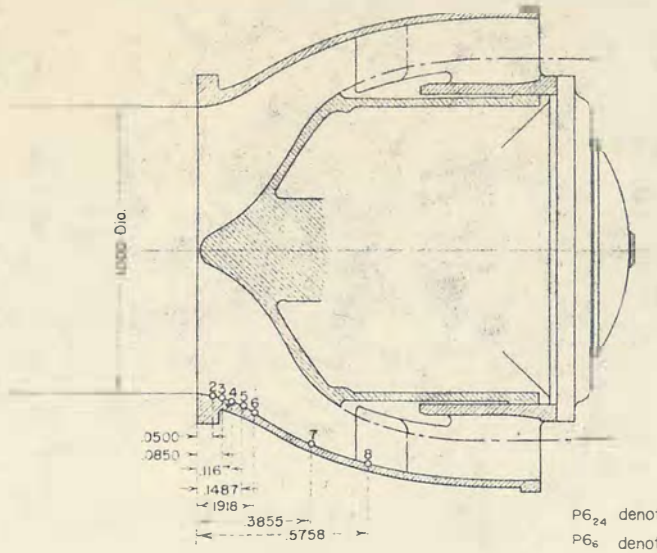
PIEZOMETER LOCATIONS

NOTES

$P17_6$ Denotes piezometer 17 on 6-inch valve
$P17_{24}$ Denotes piezometer 17 on 24-inch valve
σ Coefficients from 24-inch valve



COMPARISON OF PIEZOMETRIC PRESSURES ON 24 INCH HOLLOW JET VALVE TESTED AT BOULDER DAM AND 6 INCH HOLLOW JET VALVE TESTED IN LABORATORY



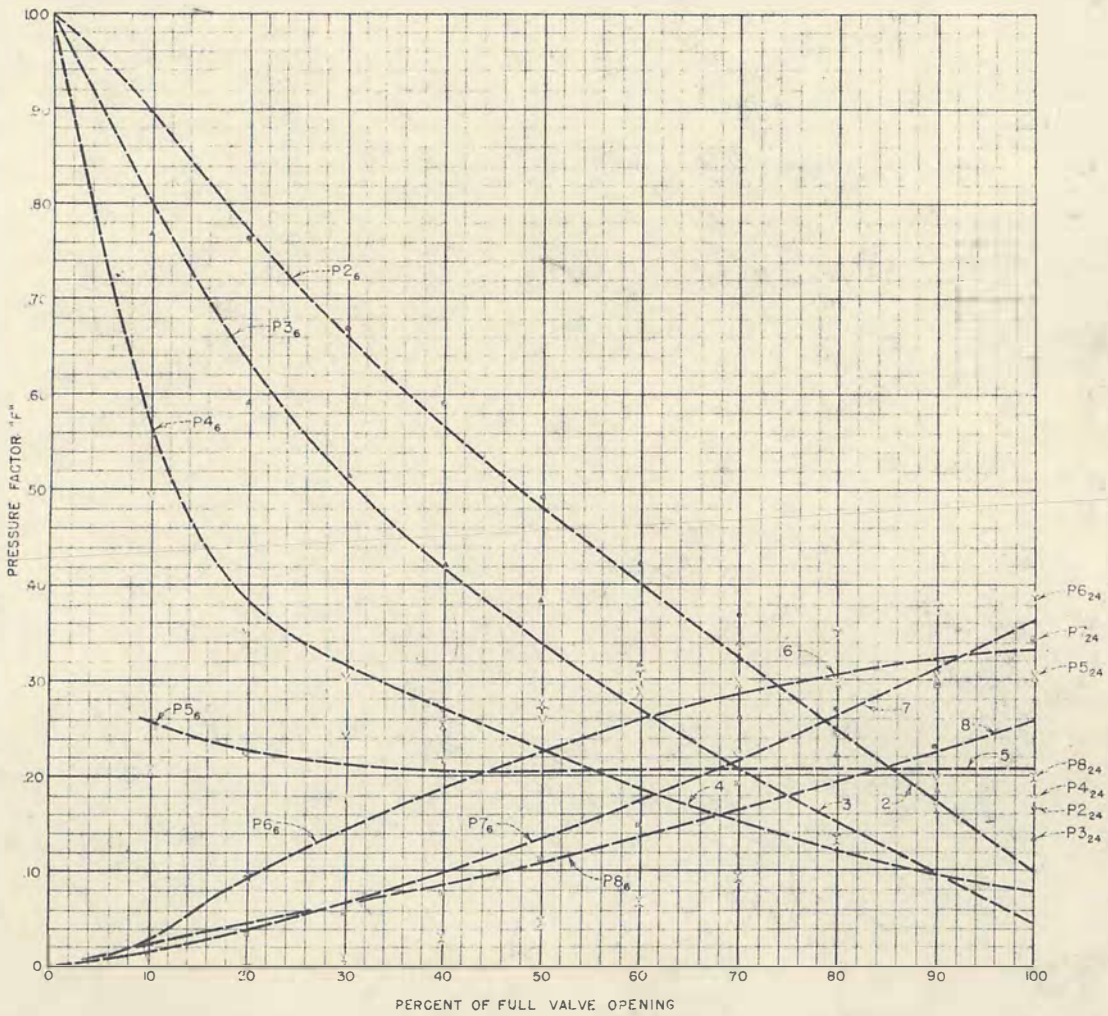
NOTES

$P6_{24}$ denotes piezometer 6 on the 24-inch valve

$P6_6$ denotes piezometer 6 on the 6-inch valve

SECTION THROUGH VALVE

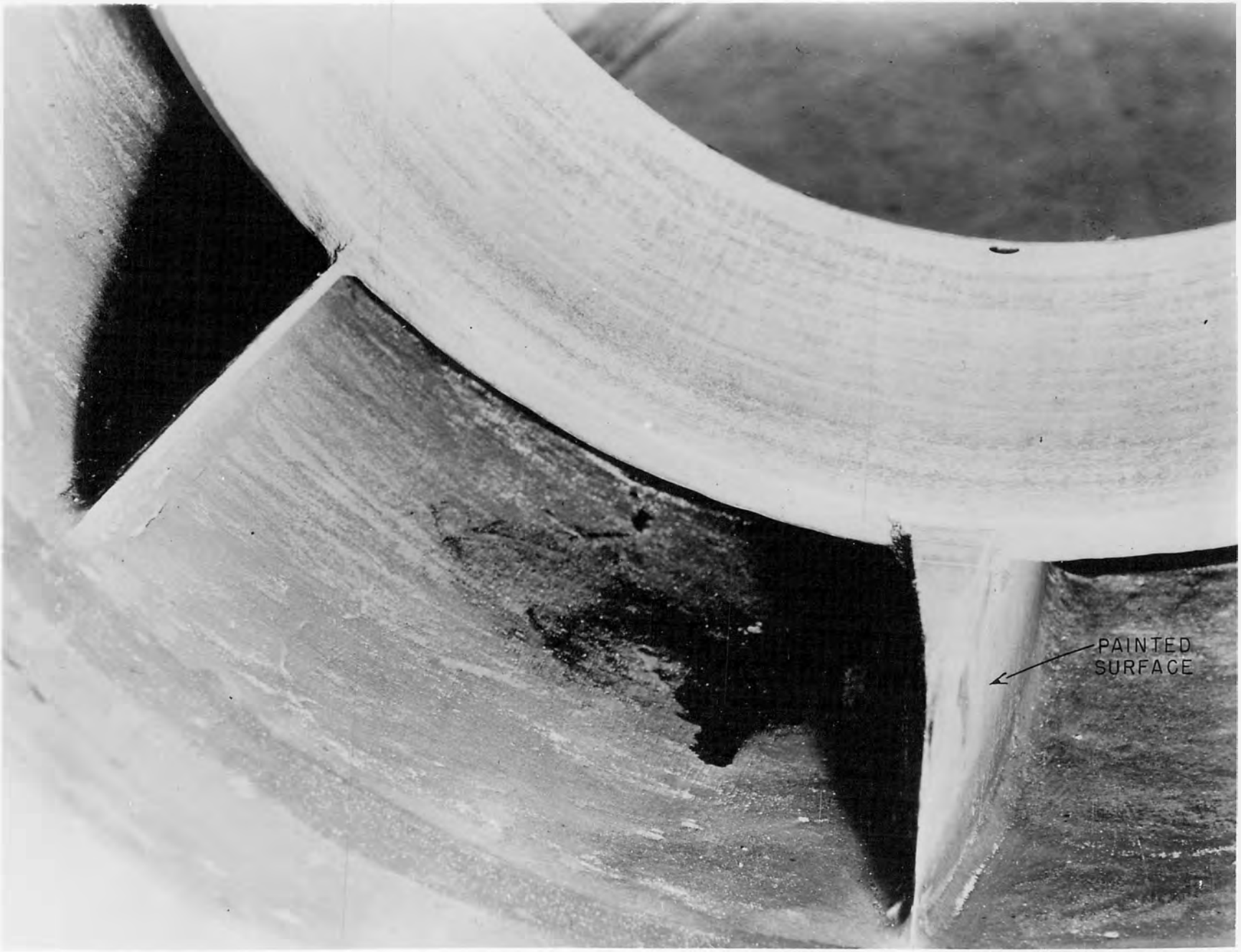
PIEZOMETER LOCATIONS



COMPARISON OF PIEZOMETRIC PRESSURES ON 24-INCH VALVE BODY AT BOULDER DAM TEST INSTALLATION AND 6-INCH VALVE TESTED IN HYDRAULIC LABORATORY

FIGURE 12

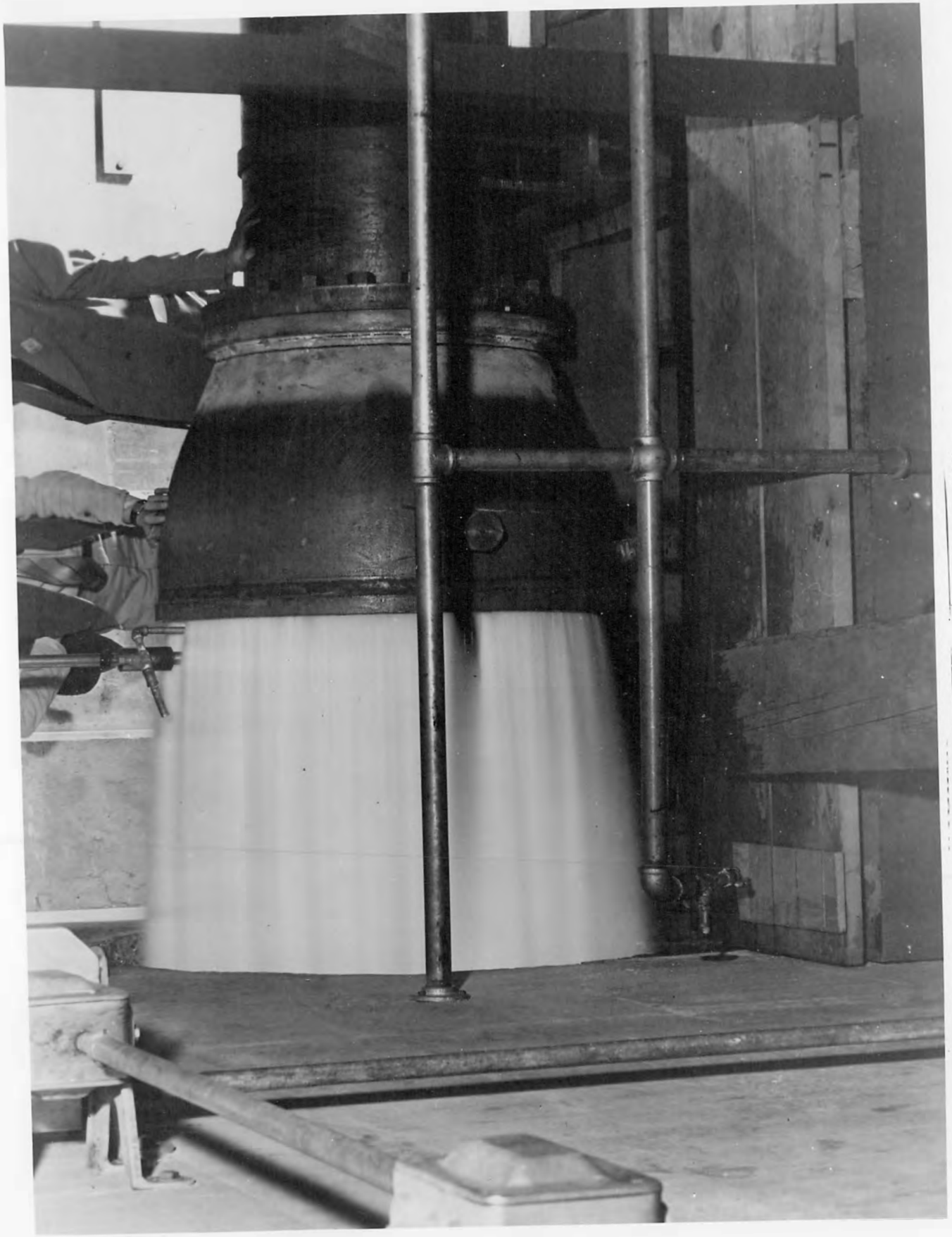
UNDAMAGED PAINT SURFACE INDICATING THE ABSENCE OF CAVITATION



UNDAMAGED PAINT SURFACE

FIGURE 13

FIGURE 14



CLOSEUP OF VALVE AND JET

A. Valve opening 10 percent

B. Valve opening 30 percent

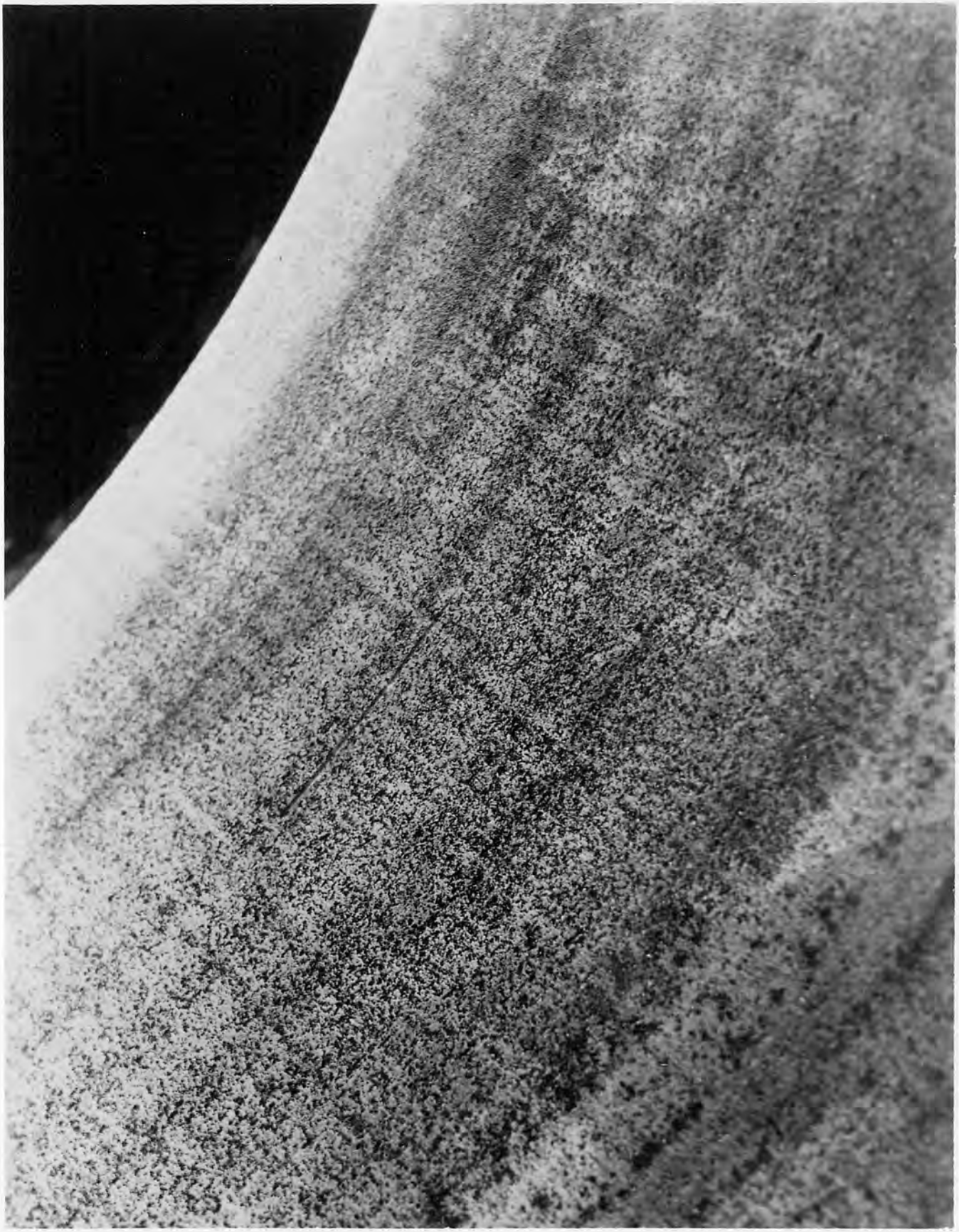
JET FROM 24-INCH HOLLOW-JET VALVE

A. Valve opening 50 percent

B. Valve opening 100 percent

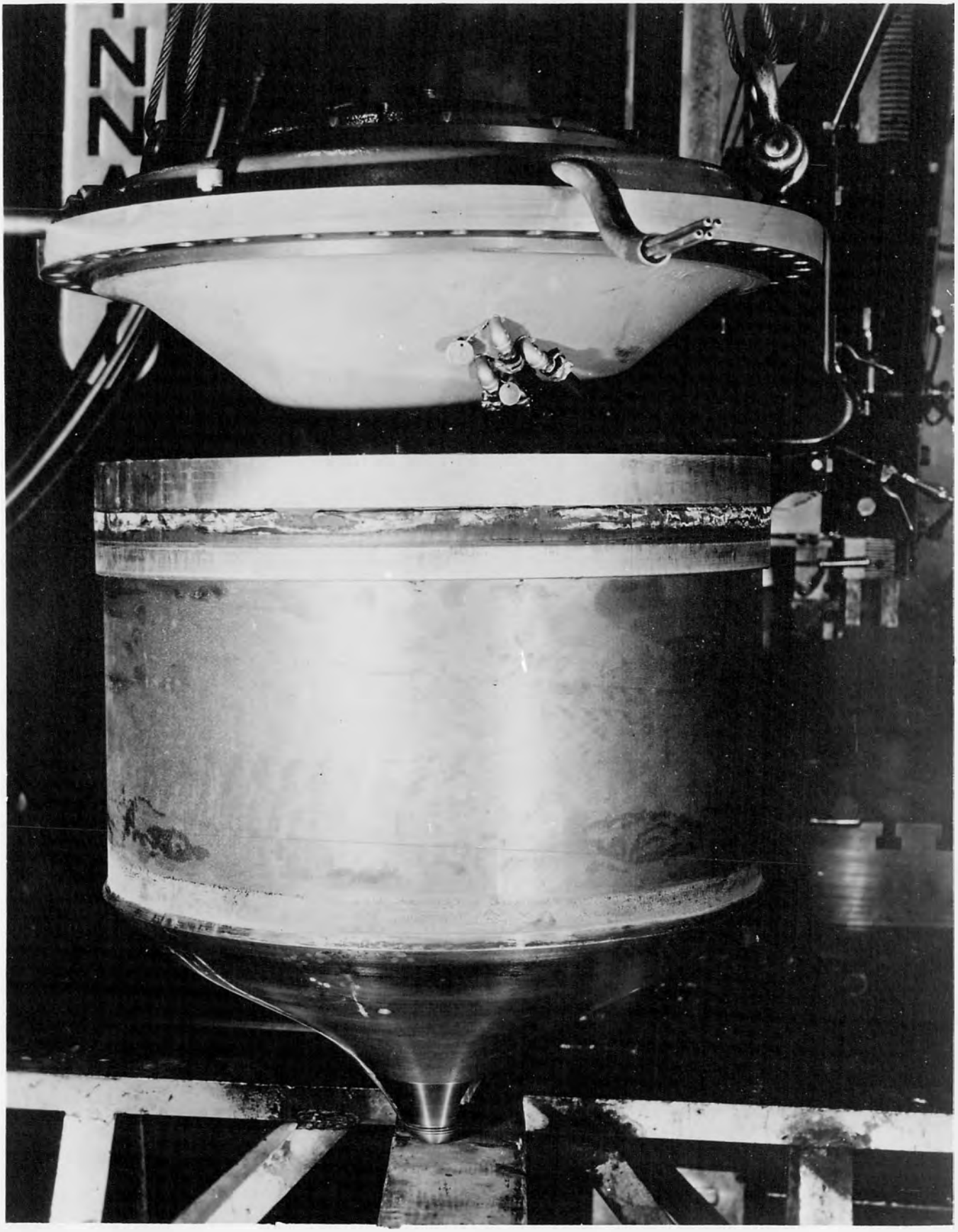
JET FROM 24-INCH HOLLOW-JET VALVE

FIGURE 17



CLOSEUP OF SPRAYED METAL BODY LINER

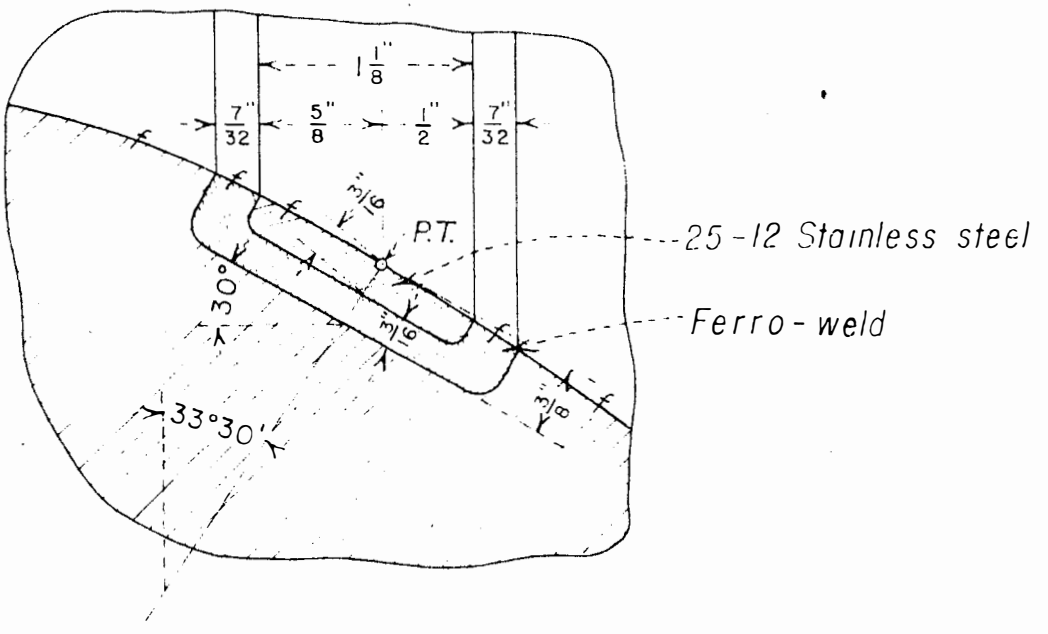
FIGURE 18



NEEDLE ASSEMBLY

FIGURE 19

CORROSION OF CAST IRON SURFACE OF NEEDLE



REVISED DETAIL B OF DWG. 341-D-97

NOTE

If necessary grind finished surface to valve contour.

SEAT REVISION OF 24" HOLLOW-JET VALVE

7-20-45