ADDRESS ALL COMMUNICATIONS TO
THE CHIEF ENGINEER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CUSTOMHOUSE
DENVER, COLORADO

OFFICE OF THE CHIEF ENGINEER

May 15, 1940.

From Associate Engineer C. W. Thomas

To Chief Engineer

Subject: Report on inspection trip to correlate hydraulic laboratory design and the field operation of 102-inch River Outlets - Grand Coulee Dam - Columbia Basin Project.

1. Reference is made to office letter of March 11, 1940 to Supervising Engineer, Coulee Dam, Washington, subject "Pressure measurements in 102-inch outlet conduits - Grand Coulee Dam - Columbia Basin Project," and to memorandum from C. W. Thomas to Engineer J. E. Warnock dated September 15, 1938, subject "Piezometers in Outlet Works - Grand Coulee Dam - Columbia Basin Project."

2. This report covers only the observations made and the tests completed during the period from March 13, 1940 to April 16, 1940. Additional observations and data will be taken by the project engineers and forwarded to this office during the period April 16, 1940 to approximately July 15, 1940. When this information is assembled and analyzed a more comprehensive report will be prepared.

3. The reservoir water surface on March 13, 1940 was Elev. 1018.3. The inflow to the reservoir was approximately 58,000 second-feet and 56,600 second-feet were being passed through the dam by seventeen of the lower outlets. During the period from March 13 to March 25, gages and equipment were installed at the terminals of the piezometer leads in the Elevation 1000 gallery, the necessary personnel secured and arrangements completed for the conduct of the pressure tests on the Elev. 1036.67 outlet. Observations were made of flow conditions through the lower outlets, in the spillway bucket and in the river downstream. The interior of the east outlet in block 51 at Elevation 1036.67 was inspected. All piezometer openings and leads were clear. Rough paint surfaces surrounding the piezometer openings were smoothed with a slice bar and the entire conduit cleaned of all foreign material (figures 1, 2 and 3.) During the period March 13-25, the inflow to the reservoir decreased to 51,000 second-feet and the release was reduced to 39,500

second-feet through ten lower outlets. The reservoir water surface was raised to Elev. 1049 or approximately 12 feet above the centerline of the intermediate outlets.

4. The east outlet in block 51 at Elev. 1036.67 was opened at 10:30 A.M., March 25, 1940. During the period March 25 to April 6, 1940, a series of six hydrostatic pressure measurements were made on this outlet using the embedded equipment described in the reference memorandum from C. W. Thomas to J. E. Warnock. These hydrostatic pressure measurements were made with the reservoir ranging from Elev. 1049.6 to 1063.8. One of the series of readings was made with the air vents to the control gates closed. The hydraulic conditions at the entrance and exit of the outlets, in the spillway bucket and in the tailraces were observed, discharge measurements through the outlets obtained from the downstream gaging station in the river, and still and motion pictures made of the hydraulic phenomena.

5. During the period April 6 to April 16, 1940, a preliminary analysis of data was completed and minor changes made in the equipment and test technique. Inconsistencies in the pressure data were found and the reason sought. The upstream gate in the east outlet in block 51 at Elev. 1036.67 was closed April 12, 1940 and the interior of the tube downstream from the gate inspected. An inspection of the conduit lining upstream from the gate was not possible because that portion of the tube was submerged by the reservoir. The paint around the piezometer openings in the accessible part of the tube had been badly damaged by the flow and in some instances the taps were partially covered by rolls of paint. It was necessary to remove the remaining paint surrounding the piezometric taps, grind the plugs flush with the conduit lining and restore the radius on the edge of the orifice before proceeding with the tests. These remedies were necessary to obtain a smooth approach to the pressure taps. Without such an approach hydrostatic pressure readings are inconsistent and small projections into the flow produce erroneous readings. Changes in gage connections and test technique simplified the pressure readings. A detailed memorandum in regard to the operation of the equipment and additional data desired was prepared and copies furnished to the interested parties. A memorandum was prepared for the Supervising Engineer concerning the completed tests and additional data to be obtained. A copy of that memorandum is attached.

6. The results of the pressure measurements are shown on figures 4, 5 and 6. A comparison of the pressures obtained from the 1:17 scale model and those obtained from the prototype for similar heads is shown on figure 4. The general characteristics of the pressure curves are quite similar, but the hydrostatic pressures in

the prototype are slightly greater than the pressures in the model. The pressure curves shown are for low heads only and the relationship may change for the higher heads. Figure 5 shows a comparison of the pressures with the air vents to the control gates open and with these vents closed. The conduit does not flow full when the air vents are open. This is true for the entire range of heads tested. For the low head, a large air bubble in the top of the pipe extends from the control gates to the downstream portion of the elbow. This bubble decreases in size as the head increases (figure 6). It should entirely disappear with a slight additional head.

7. The hydraulic conditions at the entrance to the outlets are good. Small vortices are present inside the trashracks when the lower outlets are operating under approximately 90-foot head. For heads from 12.5 feet to 27 feet on the centerline of the Elev. 1036.67 outlets, the entrance conditions are good. With a head of 12.5 feet, the right outlet only in block 51 was opened. A slight whirl developed near the intersection of the right end of the trashrack and the face of the dam inside the trashrack but there was no serious disturbance at any time and no drop in water surface over the opening of the tube. For the higher heads a vortex develops in the same location as the whirl. When both outlets in the same block are open, two well-developed vortices form inside the trashrack. The one on the right side forms near the junction of the trashrack and the wall projecting from the face of the dam and rotates in a clockwise direction. The other vortex develops in a similar position on the left side and rotates counter-clockwise. These vortices are caused by a flow along the face of the dam and around the walls. They are of small proportions and at no time are large quantities of air drawn into them. There is no noticeable drop in head through the trashracks.

8. Flow conditions at the exit of the conduit and down the face of the spillway are satisfactory. When the air vents to the control gates are open, air is drawn into the conduit and causes a "belching" effect when this air is expelled from the exit of the tube. This disturbance continues down the face of the spillway and causes an intermittent spreading of the jet. The openings to the discharge channel air vents are covered at times due to this spreading. However, on the whole the discharge conditions are very good. The jet follows the face of the spillway from the exit to the tailwater and in no place does it show signs of springing clear. There is a nominal disintegration of the jet, but very little spray until it impinges on the tailwater (figure 7). The discharge channel air vents for the Elev. 1036.67 outlets were observed to function properly. No means of measuring the air demand to these vents was available, but spray and curing water was drawn into the 6-inch inlets when the conduits were discharging. A number of these vents

are clogged with waste materials from construction. Although it is not necessary that they be cleaned before the high water this season, long periods of operation should be avoided until the cleaning is completed and the vents are operating properly.

9. The hydraulic conditions in the bucket when the Elev. 936.67 outlets are discharging very closely resembles the action observed in the models. A line of boils appears over the bucket lip. The surface flow divides at this point, a portion returning toward the dam and the remainder proceeding downstream (figure 8). The water surface along the face of the spillway is approximately 10 feet lower than the average crest of the line of boils. This differential increases when the Elev. 1036.67 outlets are opened. The lower water surface along the face of the spillway causes logs and floating debris to collect in that area. This material is unsightly and is thrown against the face of the dam by the action of the water. Some scouring of the concrete results. The water surface over the bucket will remain low throughout the range of operation of the outlets and the spillway, hence it may be necessary to provide a rake to remove floating debris periodically. No unexpected hydraulic phenomena were observed in the spillway bucket. For the combination of openings and heads that prevailed during the observations the hydraulics are satisfactory.

10. With certain combinations of outlet openings, a large slow eddy develops in the right tailrace. The flow from the outlets strikes the river bank near the junction with the tailrace excavation and is turned to the right and upstream. The current then continues across the tailrace striking the powerhouse foundation near the center approximately perpendicular to the axis of the dam. The current has sufficient velocity to fill the central wheel pits before the end pits are filled (figure 9). A similar condition may result from the operation of the drum gates near the end of the spillway. If gates near the center of the spillway are operated the flow will continue down the river without impinging on the banks of the tailrace excavations.

11. There are no serious negative pressures in the bonnets of the upstream gates in the Elev. 1036.67 outlets during the opening or closing cycle or during operation at the low heads. The vents supply sufficient air to relieve the negative pressure during periods of partial openings. There is a very noticeable chattering of the seal rings, particularly during approximately the last one-quarter of the travel of the closing cycle. This chattering continues after the gates have reached the closed position and until the seal pressure is applied. There is considerable leakage past the upstream gates with the 50-pound air pressure applied to the seals. The hoist

motors on the gates are rusting due to the high relative humidity in the gallery. The motors and hoist mechanism are covered with canvas, but it is almost impossible to secure complete protection from the cooling water, grout and other construction waste. Although it is not possible at Grand Coulee Dam, in the case of Shasta Dam, where a tube valve control will be used, much will be added to the life of the equipment if the controls and motors are installed after construction is completed and a clean-up is made.

12. The discharge data is shown in figures 10 and 11. The discharge for the lower outlet (figure 10) is based on the rating table for the river downstream as determined by the U. S. Geological Survey. The data shown on the curve were obtained before the intermediate outlets were opened. The discharge for the intermediate outlet (figure 11) was determined by taking the difference between the river discharge and the discharge through the lower outlets shown on figure 10. Both curves are based on a relatively small range of heads and caution must be employed in extrapolating the data. Additional data for extension of the curves will be available at a later date.

13. For the range of heads observed, the general hydraulic operation of the outlets is quite satisfactory. Unless changes are necessary, due to the different type of control proposed for the Shasta Dam outlets, the present design will give satisfactory hydraulic conditions. The Elev. 1136.67 outlets in Grand Coulee Dam may be operated under low heads for diversion of the river during the high water this season. The vents to the gates in both the Elev. 1036.67 and the Elev. 1136.67 outlets will draw considerable air until the head on the centerline of the gates exceeds approximately 35 feet. To avoid negative pressure in the conduits and possible damage to the lining, these vents must be open when the gates are being opened or closed. When water is flowing through the conduit they may remain closed without greatly affecting the hydrostatic pressures.

14. Sixteen millimeter motion pictures were made of the hydraulic conditions described in this report. These films are filed in the hydraulic laboratory.

Encl.

- - -

C. W. Thomas

Report approved and copies, in triplicate, forwarded to supervising engineer, Coulee Dam, Washington.

S. O. Harper,
Acting Chief Engineer.

May 31, 1940.

ADDRESS ALL COMMUNICATIONS TO
THE CHIEF ENGINEER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CUSTOMHOUSE
DENVER, COLORADO

OFFICE OF THE CHIEF ENGINEER

Coulee Dam, Washington
April 15, 1940.

MEMORANDUM TO SUPERVISING ENGINEER
(C. W. Thomas)

Subject: Pressure measurements on 102-inch outlet conduits - Grand Coulee Dam.

1. Reference is made to your letter of March 1, 1940, and to your telegram of March 8, 1940 on the above subject.

2. Since my arrival at the project from the Denver office, I have installed gages and equipment at the terminals of the piezometer leads in the Elevation 1000 gallery and have evolved a technique for obtaining the desired pressure readings and pertinent data. Recordings of the existing pressures in the east outlet at elevation 1036.67 in block 51 have been completed for reservoir elevations ranging from 1049.3 to 1063.8. A total of six sets of readings have been made, one while the air vents to the gates were closed. During this period through the cooperation of Mr. B. A. Hall, I have been assisted by men who are under the direction of Mr. L. J. Snyder. These men, having assisted with the tests to date are familiar with the technique which has been developed and are aware of the nature of the data that are required. They will retain such equipment, from that which I brought here, as is necessary until the tests are completed. The equipment should then be returned to the hydraulic laboratory of the Denver office. Sufficient data sheets have been provided and I have written a memorandum to Mr. Snyder covering the details of the operation of the equipment. I feel that his organization is fully competent to complete the tests and I may return to my duties in the Denver office.

3. Runs numbered 1 to 6 inclusive have been completed. While the reservoir level remains constant, one run should be made with both tubes in block 51 open to determine what effect the operation of adjacent outlets has upon the flow conditions. This run should be made with the reservoir water surface at or near elevation 1063.5. Additional runs should be made on the 1036.67 outlet with the reservoir water surface at elevation 1065, 1075, 1095, 1115, 1135, 1155 and at the maximum level that the reservoir reaches during high water. This is assumed to be approximately 1180. It is not necessary that the reservoir be at exactly the above elevations when the readings are taken.

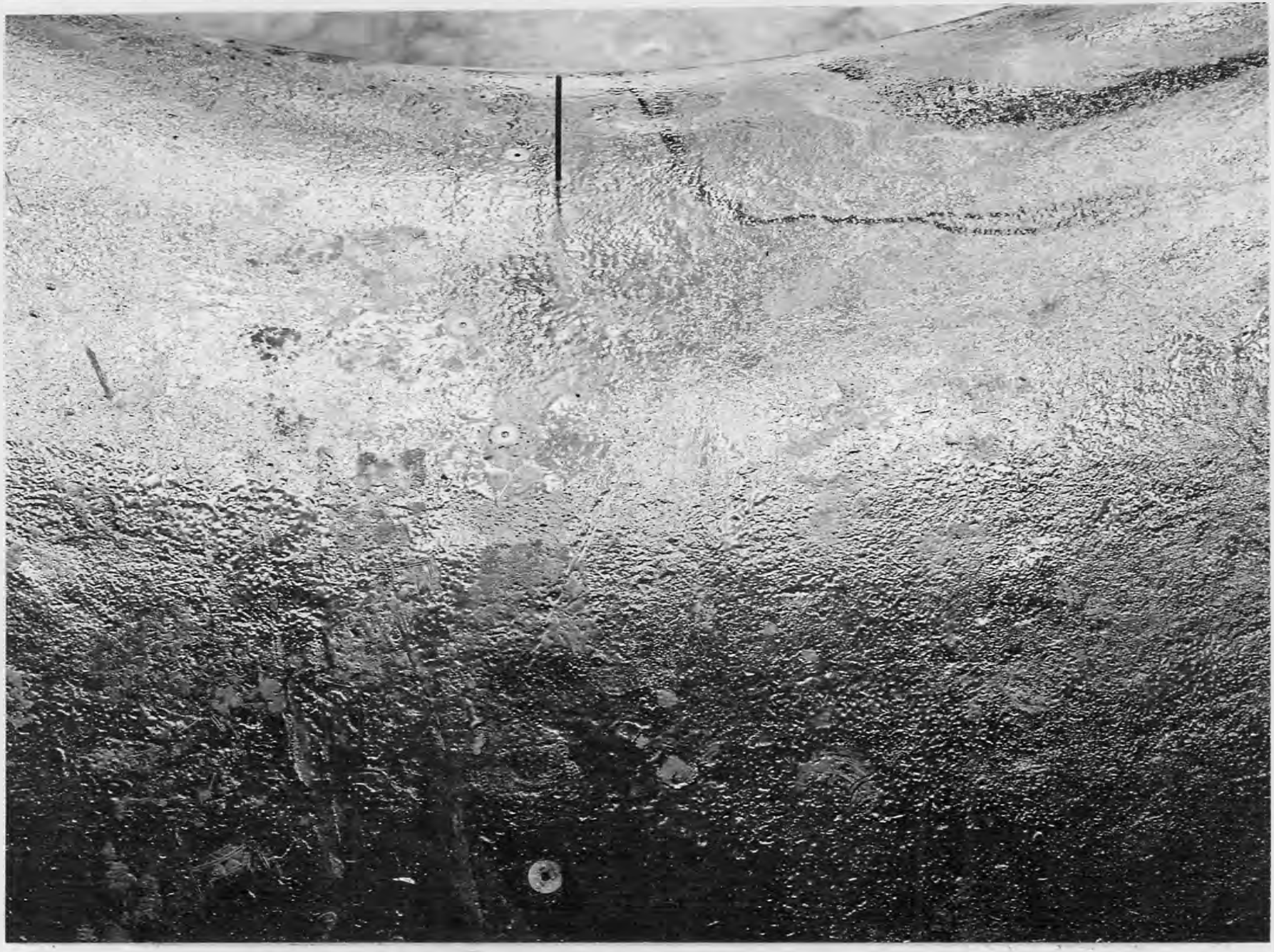
However, they should be as close as is practicable. The runs can probably best be made during daylight hours as this will facilitate observations of flow conditions. Runs should be made on the 1136.67 outlet with the reservoir water surface at elevation 1145, 1155, 1165 and at the maximum level that the reservoir reaches during high water. Instructions regarding the tests on the 1036.67 outlet will apply also to the 1136.67 outlet. It will be necessary to complete the checking of the permanent installation for the 1136.67 tube and to paint areas around the piezometer openings as was done in the 1036.67 tube. These paint areas in the 1036.67 outlet have been badly damaged by the flow and are being repainted at the present time. The time available between now and high water might permit the application of more stable paint in the 1136.67 outlet. The interior of the outlet tubes should be inspected occasionally.

4. The testing on the outlets is being done to determine their operating characteristics from a hydraulic viewpoint. Observations of pressures in the tube, discharge through the tube, entrance and exit conditions, flow conditions in the spillway bucket and observations of other hydraulic phenomena are included in the tests. Certain data are necessary to determine these factors. Pressure readings in the tube are made by means of the piezometric openings. The details of this operation have been outlined in my memorandum to Mr. Snyder. Observations on the discharge through the tubes will be determined from reservoir elevation readings and river gage readings, below the dam. In this connection the observed data should be supplemented by a black line print of the monthly hydrograph sheet from the river recording gage and a print of the completed readings entered on form L-2363-1 for the months during which the tests are in progress. A number of pictures showing the entrance and exit conditions of flow through the outlets and the action of the spillway bucket should be taken as a part of the data. Notes should be kept regarding any peculiar or unexpected flow conditions. Carbon copies of all written data should be retained by the project until it is determined that the originals have been received in Denver.

5. All data sheets, prints and photographs with appropriate identifications should be assembled and forwarded to Denver by Mr. Cook each time he returns to that office from the project. This would assure prompt delivery to the interested individuals and would lessen the possibility of loss in transit.

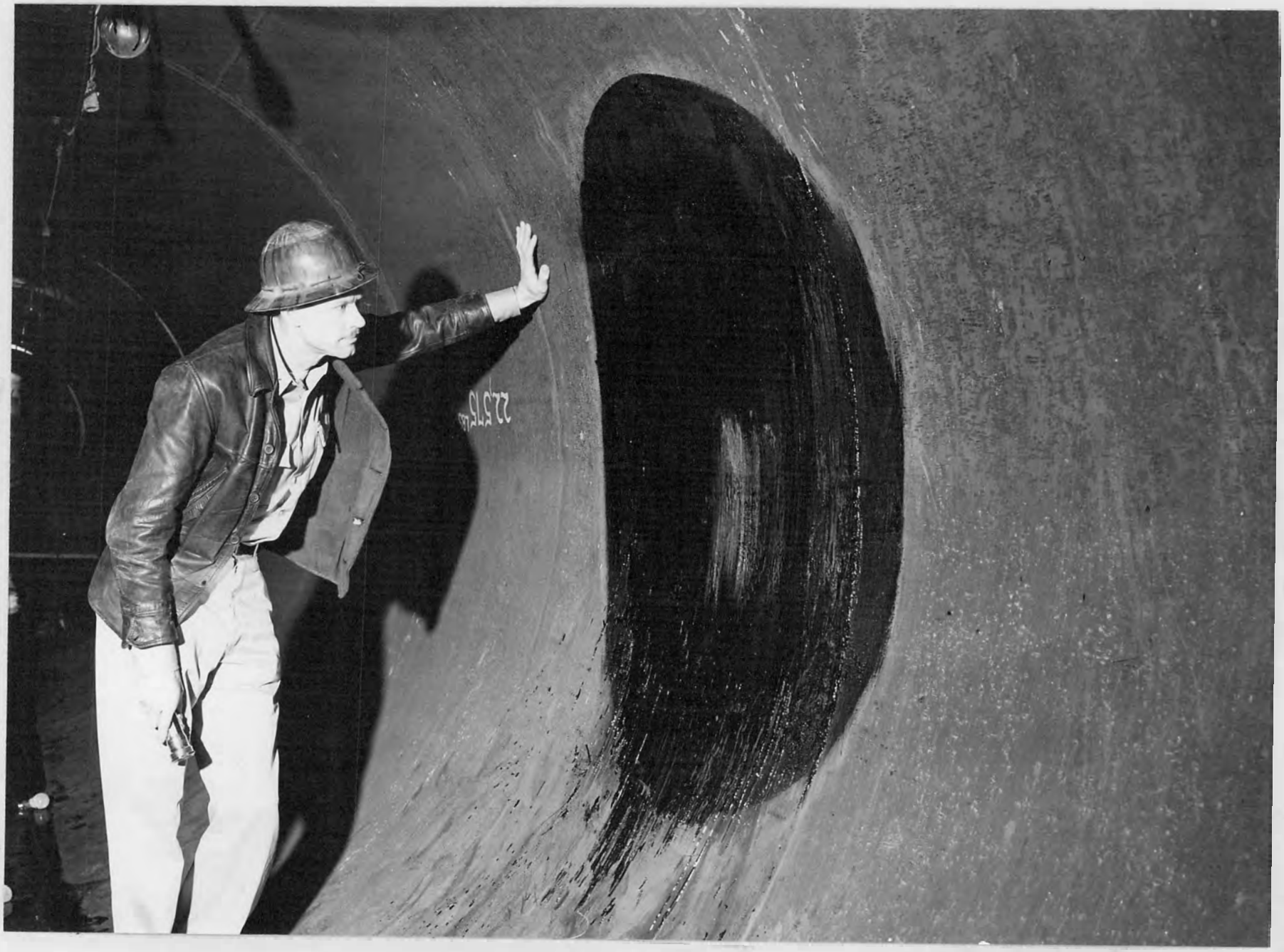
cc-Construction Engineer
Chief Inspector
L. J. Snyder

/s/ C. W. Thomas.



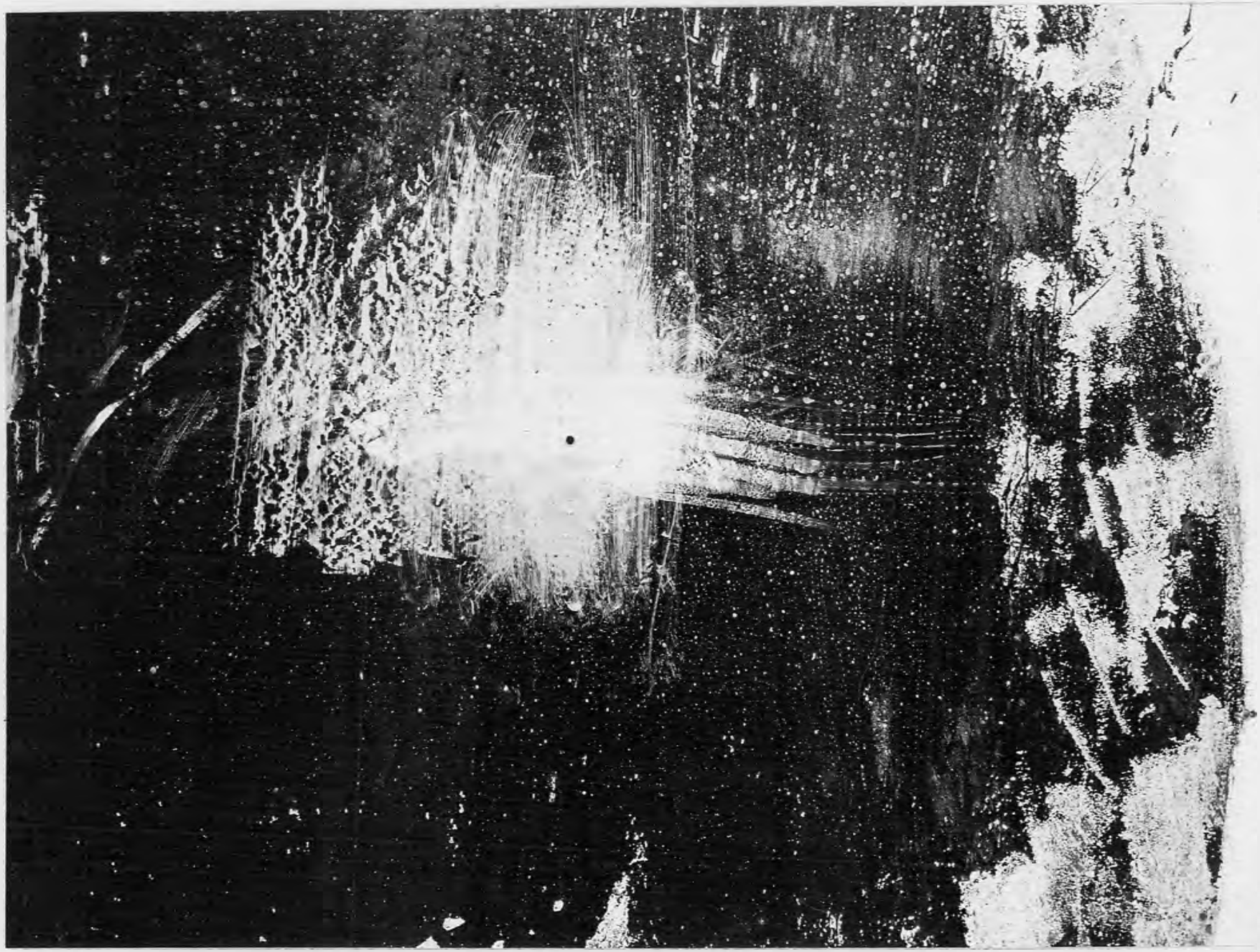
PIEZOMETER TAPS IN BELLMOUTH ENTRANCE - BEFORE RUNS - MARCH 14, 1940

FIGURE 1



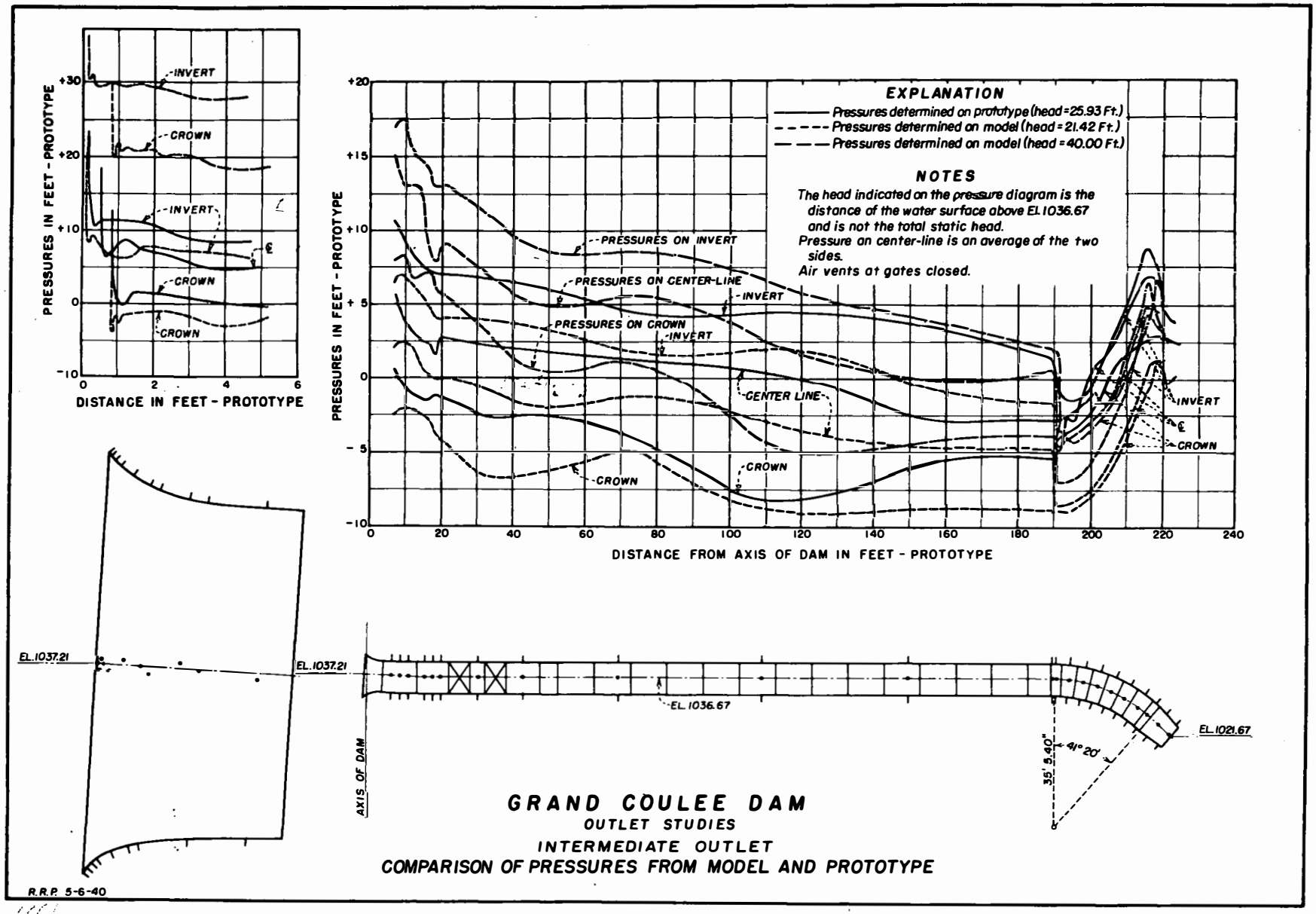
TEMPORARY PAINT PATCH AROUND PIEZOMETER TAPS IN PLATE STEEL LINING - BEFORE RUNS - MARCH 14, 1940

FIGURE 2



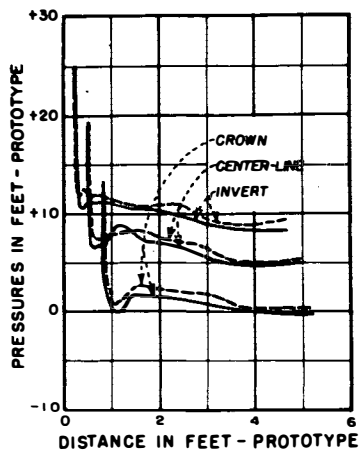
PIEZOMETER TAP IN PLATE STEEL LINING - BEFORE RUNS - MARCH 14, 1940

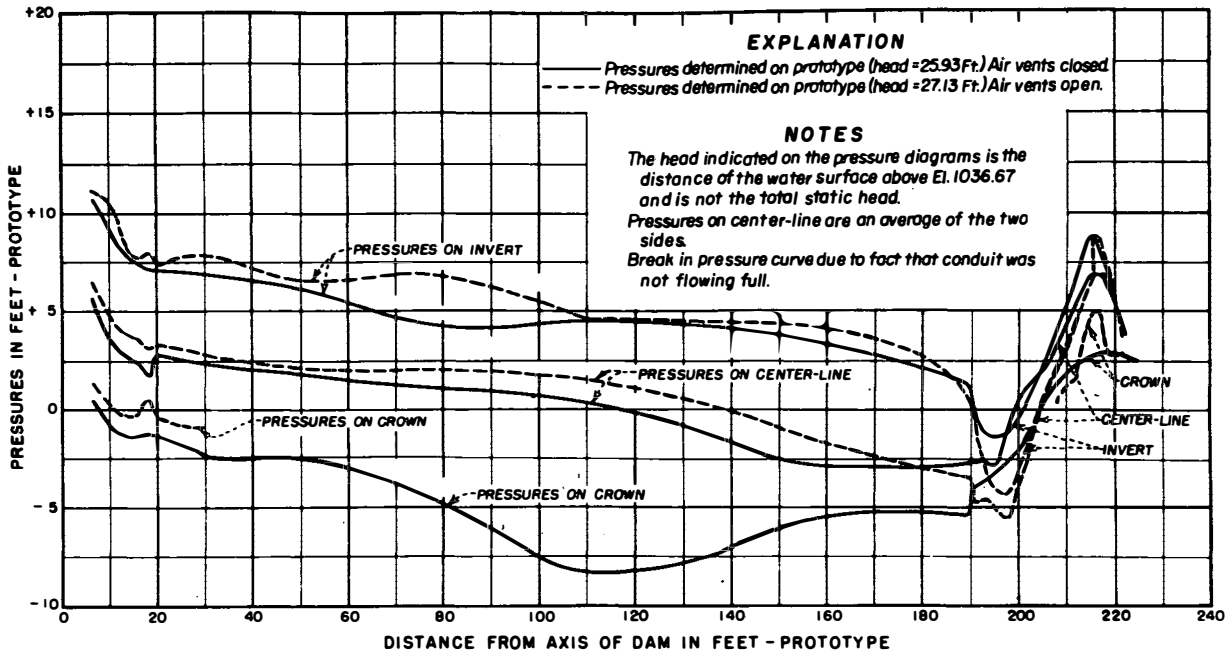
FIGURE 3

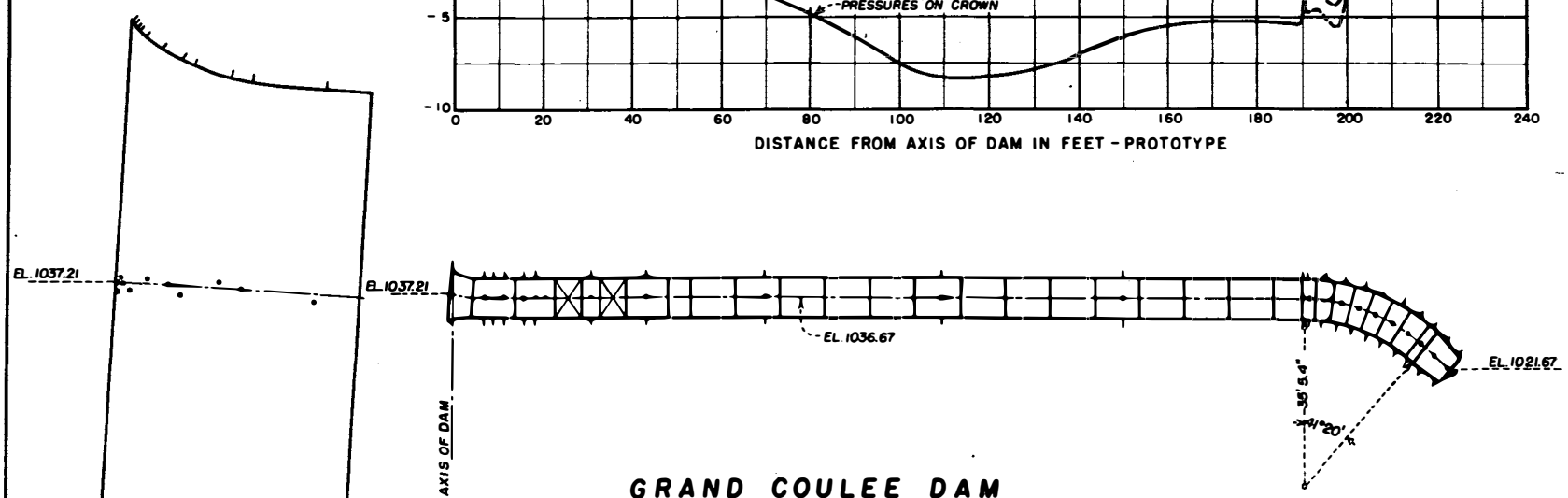


GRAND COULEE DAM
OUTLET STUDIES
INTERMEDIATE OUTLET
COMPARISON OF PRESSURES FROM MODEL AND PROTOTYPE

FIGURE 4







GRAND COULEE DAM

OUTLET STUDIES

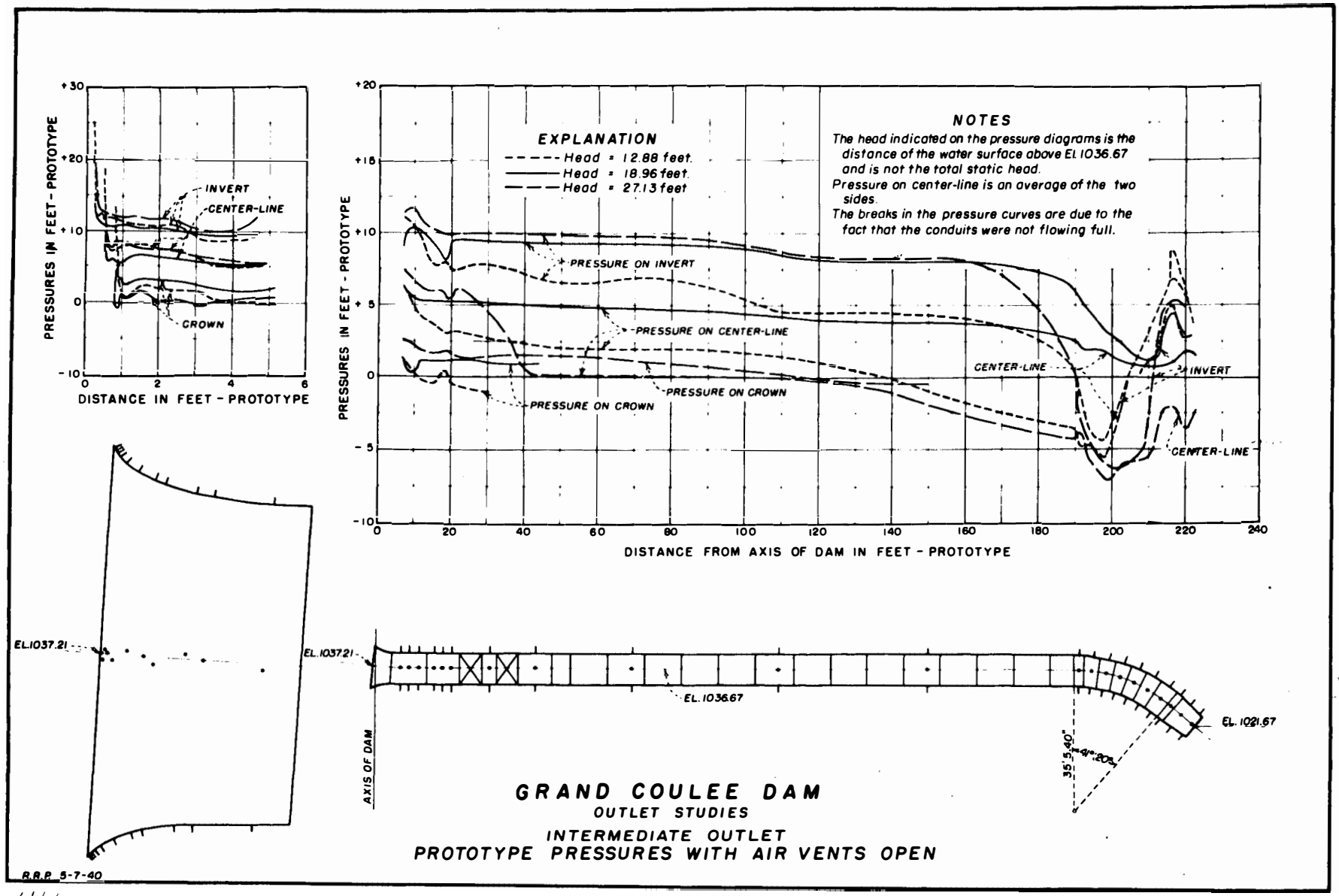
INTERMEDIATE OUTLET

PROTOTYPE PRESSURES WITH AIR VENTS OPEN AND CLOSED

R.R.P. 5-7-40

141

FIGURE 5



GRAND COULEE DAM
OUTLET STUDIES
INTERMEDIATE OUTLET
PROTOTYPE PRESSURES WITH AIR VENTS OPEN

FIGURE 6

141

EAST OUTLET IN BLOCK 51 AT ELEVATION 1036.67 DISCHARGING - RESERVOIR ELEVATION 1059.4 - MARCH 28, 1940

FIGURE 7

FLOW CONDITIONS IN BUCKET - 18 LOWER OUTLETS AND ONE INTERMEDIATE OUTLET DISCHARGING - RESERVOIR ELEVATION 1063.4 - DISCHARGE 76,900 SECOND-FEET - MARCH 30, 1940

FIGURE 8

EDDY IN RIGHT TAILRACE - DISCHARGE 93,840 SECOND-FEET - APRIL 8, 1940

FIGURE 9

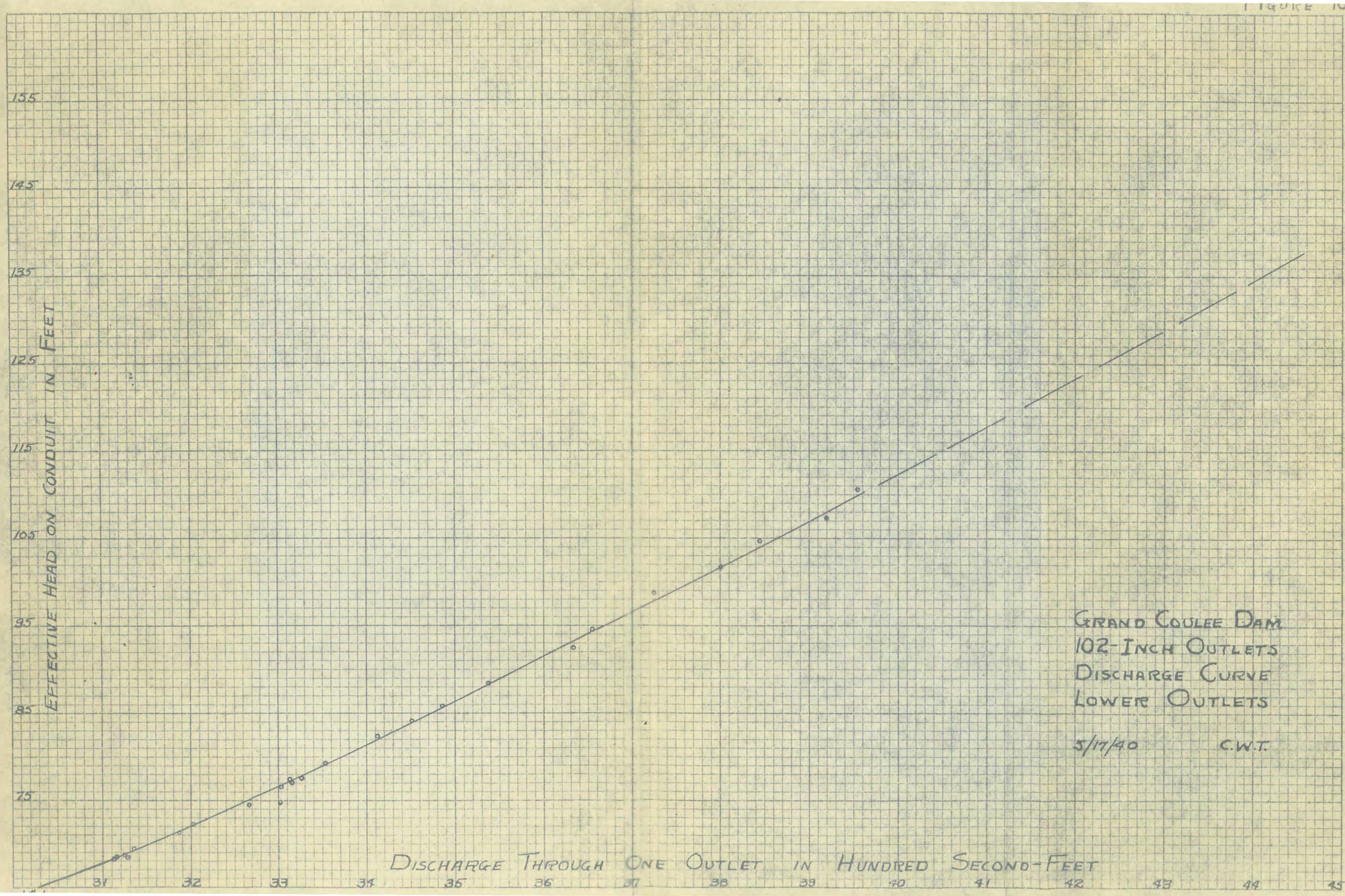
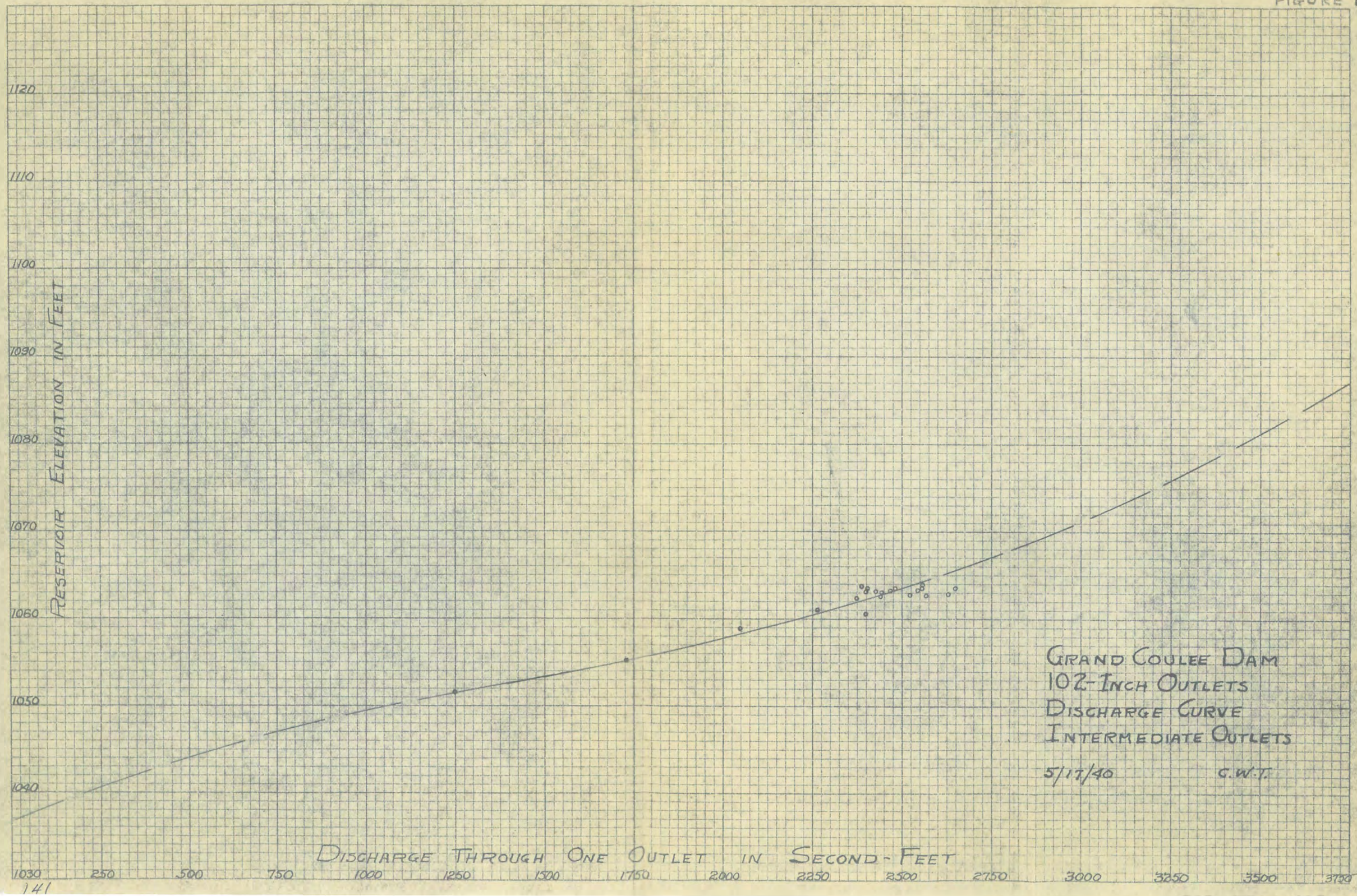

155
145
135
125
115
105
95
85
75
EFFECTIVE HEAD ON CONDUIT IN FEET
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
DISCHARGE THROUGH ONE OUTLET IN HUNDRED SECOND-FEET
GRAND COULEE DAM
102-INCH OUTLETS
DISCHARGE CURVE
LOWER OUTLETS
5/17/40
C.W.T.

FIGURE 11


1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
RESERVOIR ELEVATION IN FEET
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
DISCHARGE THROUGH ONE OUTLET IN SECOND-FEET
GRAND COULEE DAM
102-INCH OUTLETS
DISCHARGE CURVE
INTERMEDIATE OUTLETS
5/17/40
C.W.T.