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CORPS OF ENGINEERS, U. S. ARMY

MISSISSIPPI RIVER COMMISSION

SLIDE GATE TESTS, NORFORK DAM
NORTH FORK RIVER, ARKANSAS

PRELIMINARY REPORT



TECHNICAL MEMORANDUM NO. 2-280

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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FRONTISPIECE. Norfolk Dam, North Fork of the White River, Arkansas

PREFACE

In a letter to the Division Engineer, Southwestern Division, dated 23 November 1945, subject: "Slide Gate Tests," the Office, Chief of Engineers, proposed a series of slide gate tests to be made at Norfork Dam, Arkansas. Actual authorization of the tests was contained in the 4th indorsement to the initiating letter. The prototype tests were supervised by the Little Rock District Office under the general direction of the Office, Chief of Engineers. The Waterways Experiment Station provided all measuring equipment and personnel for its operation. This report was prepared by the Waterways Experiment Station in collaboration with the Little Rock District and the Office, Chief of Engineers. It is factual in nature, containing only a presentation of data, together with a few brief, readily-apparent conclusions. It is planned to prepare a more comprehensive report on the tests after a thorough analysis of the data has been made. Also, at that time, additional observations regarding the 45-degree gate lip (type B), which is undergoing a long-time test at partial opening, will be included.

SUMMARY

Results of full-scale tests of two types of slide gates under high heads at Norfolk Dam, Arkansas, indicated that the performance of a gate with a 45-degree upstream bevel at the lower edge (type B) was superior to that of the Norfolk-type gate (type A) which had a flat bottom with a slight slope to fit the sealing surface. High negative pressures on the gate bottom, considerable gate vibration, and crackling sounds characteristic of cavitation were noted for most gate openings of the Norfolk gate. By contrast, high positive pressures occurred over the sloping bottom of the 45-degree gate, resulting in elimination of cavitation sounds and in a marked reduction in gate vibration. The high positive pressures also resulted in less air demand at partial gate opening.

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SLIDE GATE TESTS, NORFORK DAM

NORTH FORK RIVER, ARKANSAS

PART I: INTRODUCTION

1. The need for fine reservoir regulation, together with the economy of installing a few large reservoir outlets as opposed to a larger number of smaller outlets, makes it desirable to discharge under conditions of part-gate open and high reservoir heads. Operating experience at existing structures has revealed undesirable downpull, chatter, and vibration of some control gates when subjected to long periods of operation under heads greater than 75 ft.*

2. After studying available information on objectionable performance of control gates, a comprehensive gate testing program was initiated by the Office, Chief of Engineers, to develop and test reservoir outlet gates for high-head operation. Slide and tainter gates were selected for detailed investigation because of their economy, superior hydraulic performance, and structural and mechanical simplicity. The main purpose of the test program reported herein was to develop a slide gate which could be operated continuously at part-gate and under heads of 200 ft or more without undesirable cavitation or vibration.

3. Model tests on a 1:6-scale model of a typical slide gate were first undertaken to determine the most satisfactory shape of the bottom

* "Survey of Hydraulic Control Works," Missouri River Division, CE, 25 April 1947.

edge of gate, which would later be tested under prototype conditions at Norfork Dam. The prototype tests were considered highly desirable because of the large number of slide gates planned for future installation in Corps of Engineers structures.

4. The model data obtained consist of pressure measurements on seven shapes of gate lip obtained by means of 15 to 20 closely-spaced piezometers. A complete discussion of the model data will be included in the comprehensive report to be prepared after a thorough analysis of the data has been made and at a time when results of the long-time test on the 45-degree gate lip are available. On the basis of the model tests, two gate-lip shapes, described hereinafter, were selected for further investigation under prototype conditions.

5. The purpose of the prototype tests was to verify and extend the experimental data obtained on the model for the two shapes of gate lip selected for prototype testing. In addition to observations of general hydraulic performance of the gates at several part-gate openings, measurements were made of pressures on the gate lip and in the conduit a small distance downstream of the test gate, vibration of the gate in vertical and horizontal (upstream and downstream) directions, strains developed near the gate lip, and air requirements.

PART II: TEST SITE AND PROCEDURE

Norfolk Dam

6. In view of the relatively high heads available, Norfolk Dam, located in northern Arkansas on the North Fork of the White River (fig.

1), was selected as the site for the prototype slide gate tests. This dam (frontispiece and plate 1) is a concrete gravity structure 2631 ft long and 233 ft high. The spillway, located near the left abutment, is 568 ft wide and has a crest elevation of 552.* A contract will be let in the near future to in-

stall 12 tainter gates, 40 ft

wide and 28 ft high, on the spillway crest. At present vertical bulkheads 13 ft high are located on top of the spillway in lieu of the gates. The stilling basin, 568 ft wide and 181.5 ft long, has a floor elevation of 362. Two rows of baffle piers 8 ft high and a stepped end sill 6 ft in height are located on the basin floor to assist in dissipation of energy contained in spillway and sluice flows.

7. Eleven flood-control conduits, each 4 ft wide by 6 ft high, are provided through the base of the spillway section. The combined capacity

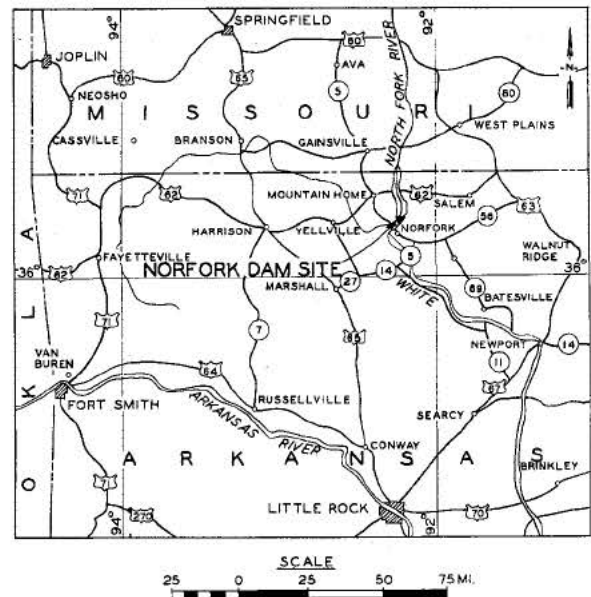


Fig. 1. Vicinity map

* All elevations are in feet above mean sea level.

of the conduits with the reservoir at spillway crest is 21,000 cfs. Each conduit has a bellmouth entrance with invert at elevation 394.99. The conduits are inclined downward on a constant slope of about 8-1/2 degrees to an intersection with the stilling basin. Each conduit is controlled by two hydraulically operated flat-bottomed gates in tandem, the downstream gate being used for normal operation and the upstream gate being reserved for emergency operation. The axes of the gate frames and leaves are in a vertical plane (plate 2). The gate and air vent slots are bevelled as shown on plate 3. The gates are fully vented and are operated from control rooms just above each conduit, which are reached through an operating gallery with floor elevation 404.4. The service gate of the conduit nearest the powerhouse was replaced by the test gates for conducting the tests described herein. With test gate sill at elevation 390.13 and reservoir water surface between elevations 550.0 and 550.4, the head on the gates during the tests was approximately 160 ft.

Test Gates

8. The first gate lip tested, designated type A, had a flat bottom with a slight slope to fit the bottom sealing surface when closed and the roof of the conduit when fully open (existing Norfolk-type slide gate). The second gate lip tested, designated type B, had a 45-degree inclined bottom with a 2-in. sealing surface on the downstream portion of the lip. The 2-in. sealing edge is required to keep bearing pressures on the gate seat within reasonable limits. A 1/2-in. vertical projection is provided in order to permit machining of the sealing edge without changing the width of bearing surface. The detailed dimensions of these gates are

shown on plates 4-7. An airtight chamber in the gate body contained the necessary measuring equipment. The change from one test gate to the other involved only removal of the oil cylinder lifting mechanism and the gate bonnet cover (photograph 1). The embedded gate frame was not disturbed during the test program.

Instrument Installations and Test Procedures

9. Data obtained in the prototype tests included average and instantaneous pressures on the gates and in the downstream conduit, gate vibration, strain measurements, and air demand. Apparatus for measuring and recording prototype data included SR-4 strain gages, six channel amplifiers, Westinghouse type P.A. recording oscillographs, Brush piezo-electric crystal vibration pickups, electric pressure cells, 24- and 100-in. mercury U-tubes, high pressure dial gages, orifice plates, pitot tube, and a Velnor air-velocity meter.

10. Each gate leaf was equipped with facilities for determining the pressure distribution on the lip surface by means of piezometers and electrical pressure cells (plates 4-9). Facilities were provided also for determining pressure conditions in the bonnet and on the conduit roof immediately downstream from the test gate. The 13 piezometers in type A gate leaf and the 11 piezometers in type B gate leaf, together with a pressure tap in the manhole cover downstream from the gate and a pressure tap on the gate bonnet, were read with a conventional 24-in., or 100-in., U-tube with mercury as the gage fluid (photograph 2). Pressures above the range of the 100-in. U-tube were recorded with a Bourdon-type dial gage. The electrical pressure cells for measurements of pressure

fluctuations were located as shown on plates 8 and 9. These cells (photograph 3) were designed and constructed by the Waterways Experiment Station especially for this series of tests. Each cell was about 1 in. in diameter, surrounded by a mounting plate approximately 2 in. in diameter. The face of each cell consisted of a thin diaphragm to the inner side of which were bonded two SR-4 strain gages. As the diaphragm was flexed under pressure or vacuum the electrical resistance varied in direct proportion to the amount of deflection. The cells were designed for use with pressures ranging from -15 to 75 psi and were calibrated prior to installation in the test gate. Recording equipment used is shown in photograph 4.

11. The horizontal and vertical vibrations of each test gate were measured with a Brush vibration pickup, a commercial product of the Brush Development Company. This instrument is of the inertia type which utilizes piezoelectric crystal elements as the generating members. The instruments were screwed to studs fastened to the test gates (plates 8 and 9). Movement of the crystal element in a direction normal to its face generated a small voltage that was approximately proportional to the acceleration the crystal received when applied to a vibrating body. To obtain a displacement record, this acceleration curve was integrated twice by an electrical circuit. A permanent record was obtained by using the camera attachment of the oscillograph. The camera, loaded with a sensitized recording paper 5 in. wide, could be driven at various speeds. This same camera attachment was used to record the pressure fluctuations with the pressure cells described in the preceding paragraph. Other apparatus used are shown in photograph 5.

12. The quantity of air required for each test gate at various openings was measured by circular orifice plates located on the inlet end of a 20-in. steel pipe specially constructed to extend the air vent to the top of dam thereby facilitating measurements (photograph 6 and plates 10 and 11). A pressure tap was located 1 in. below the orifice plate and the differential between atmospheric and tap pressures was recorded by a U-tube manometer with water as the gage fluid. The orifice plates were of the square-edged type with diameters selected to give orifice areas equal to 75, 50, and 25 per cent of the area of the 20-in.-diameter air vent extension. The method recommended by the American Society of Mechanical Engineers in its publication entitled "Flow Measurement," dated 1940, was used in transforming manometer readings to rate of air flow. A constant coefficient of discharge of 0.6 was assumed. Attempts were also made to measure air quantities with a commercial type air velometer and a pitot tube. Both methods were abandoned, however, in favor of the inlet type orifice plate.

13. Strain measurements were attempted by SR-4 strain gages mounted at strategic points on the inside of the gate in a watertight compartment. Any bending movement of the gate on which the gage was mounted resulted in a corresponding deformation of the gage and a change in the electrical resistance of the gage. The change in electrical resistance was related to stress in the gate members and thus to bending forces.

14. The desired data were recorded for gate openings of 0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 ft. Air demand data were also recorded for various sizes of orifices located on top of the 20-in.-diameter

extension to the air vents. These orifices had diameters of 20 in. (full vent area), 17.32 in. (75 per cent vent area), 14.4 in. (50 per cent vent area), and 10 in. (25 per cent vent area). Although the orifices resulted in a reduction in inlet area of the 20-in.-diameter riser pipe, they did not give results similar to those that would obtain had the entire air vent been reduced in the same proportion. However, as the diameter of the orifice was reduced it did result in increased losses at the entrance to the air vent, thereby throttling the vent to some extent. The effect of this throttling resulted in changed hydraulic performance of the slide gate. Piezometer readings were recorded for all conditions of vent opening, but pressure cell, strain, and vibration measurements were obtained only for the unrestricted vent and the smallest diameter orifice (25 per cent).

15. The general test procedure followed consisted in securing a set of pressure readings, both piezometric and electric, and measuring vibration, strain, and air demand, for the smallest gate opening and then proceeding to the next larger gate opening where the procedure was repeated. After the gate was completely opened, it was closed in 1-ft intervals and similar measurements obtained as a check on those obtained during the opening procedure. It was not possible to make discharge measurements for the various gate openings. However, a computed pool-discharge relation curve for one gate full open is inclosed (plate 12) for reference purposes.

PART III: TEST RESULTS

General Hydraulic Performance

16. Observation of the general hydraulic performance of the test gates and of the emergency gate upstream revealed some interesting facts. As the emergency gate was raised or lowered the motion was made in a series of short jerks accompanied by sharp metallic pinging and hammering sounds. Based on an earlier inspection of the gate seals by the gate manufacturer, it was concluded that the irregular emergency gate movement was due to clamping action caused by a wavy surface finish on the gate seals. This action was minimized on the service and test gates by lubricating the sliding-contact surfaces with a heavy coat of waterproof grease. Corresponding surfaces for the emergency gate could not be lubricated, but the action could be minimized by operating the gate at a slow rate of movement. Even though seals of both test gates were greased, type B gate appeared to operate more smoothly with less sound effects than type A gate, especially when the air vents were throttled. The greatest vertical vibration for each gate appeared to occur at a gate opening of 80 to 90 per cent of the conduit height. This same characteristic has been observed in model tests of other gates conducted at the Waterways Experiment Station.

17. The manhole cover in the roof of the conduit downstream from the gate (plate 2) was removed to observe flow conditions in the conduit downstream from the gates. It was observed that for small gate openings the flow was rough and concentrated in the center of the conduit with considerable spray along the side walls. This is attributed to the curved

upstream face of the gate. Excessive spray at the manhole and high-velocity air flow through the manhole into the conduit made observations impossible at openings in excess of 2 ft.

Average Pressure Measurements

18. Measurements of average pressures for various gate openings and air vent conditions, as determined on types A and B gates by means of piezometers, are presented in tables 1-10. In analyzing these data, it should be noted that for gate openings larger than about 5 ft some piezometers were located in the gate well above the conduit roof.

19. Plots of the pressure data presented in tables 2 and 7 are shown on plates 13-16. These plots reveal superior pressure conditions for type B gate, for which pressures were positive along the entire gate lip with the exception of the 2-in. sealing strip at the base. There, flow was deflected free from the 2-in. sealing strip by the 1/2-in. vertical projection at the base (plate 7) and small negative pressures occurred, being substantially equal in magnitude to the conduit pressures. Pressures were negative on the under side of type A gate for all gate openings except those less than 0.5 ft and full-gate open.

20. Pressures measured at the manhole cover on the roof of the conduit about 5 ft downstream from the test gate are shown on plate 17. These data also indicate the superiority of type B gate. In general, negative pressures in the conduit were more nearly constant and of smaller magnitude for type B gate. Throttling the air vent resulted in slightly increased negative pressures in the conduit. The low pressures at 0.75-ft gate opening for type A gate are attributed to the unfavorable shape of

gate bottom. Low pressures which occurred between 5.0- and 6.0-ft gate openings for both gates were due to the downstream conduit being nearly filled with water, resulting in maximum air requirement. The pressures recorded on the roof of the conduit were in each instance about the same as observed on the bottom of type A gate and on the 2-in. sealing edge of type B gate. Maximum negative pressures on the two test gates occurred at these locations.

21. Pressures recorded in the bonnet for type A gate are presented on plate 18. Similar data for type B gate will be obtained at a later date. The low bonnet pressures, as compared to the head on the gate, for openings in excess of 0.5 ft are caused by the clearance in the gate well on the downstream side of the gate being considerably larger than on the upstream side, resulting in low water levels in the gate well. The high pressure for a gate opening of 0.25 ft is caused by the top of the gate being in contact with the downstream seal when gate openings are small.

Instantaneous Pressure Measurements

22. Results of instantaneous pressure measurements recorded with electrical pressure cells in type B gate are shown in tables 11-19 and on plate 19. Maximum, minimum, and observed average pressures are presented as taken from oscillograph records. Actual reproductions of typical oscillograph records for most critical conditions are being prepared and will be included in the final report. All pressures were positive except on the base of the 2-in. sealing strip where a pressure of -21 ft was recorded at a 0.25-ft gate opening (table 11). Comparisons of observed average pressures as determined by pressure cells in type B

gate with those recorded by piezometers for several gate openings and two air vent conditions are shown in tables 11-19 and plate 19. These data reveal reasonable agreement between the two methods.

23. Pressure cell data are not presented for type A gate. While two attempts were made to measure pressure fluctuations for type A gate, in each attempt all cells on the underside of the gate (plate 8) were damaged. As shown on photograph 3, the diaphragm of the cell failed by being forced inward. Tests on a similar type cell in the laboratory revealed that the cell could be subjected to a steady pressure of about 490 psi before failure. Since this is about 7.5 times the head of water at Norfork Dam, it was concluded that the cell failures were caused by extremely high instantaneous pressures resulting from the collapse of cavitation pockets, or from high frequency pressure changes set up by vibration of the gate. Thus, further attempts to record pressure fluctuations on type A gate were abandoned.

Vibration of Test Gates

24. Vibrations, both in horizontal (upstream and downstream) and vertical planes for each test gate were constant, for the most part, throughout the full range of gate openings (plates 20 and 21). The vibration data represent only relative vibration; that is, the relative vibration scale of each plot is based on percentages of the maximum amplitude of recorded vibration, which occurred in the horizontal plane for type A gate. The determination of vibration amplitude in terms of dimensional quantities was beyond the capabilities of the test equipment. Vibration in the vertical plane was somewhat less pronounced for type B

gate. In the horizontal plane, vibration of type B gate was considerably less than that of type A gate. The vibration measurements provide additional evidence of the superiority of type B gate.

25. The vibration data are also being studied with a view to presenting frequency data in the final report. An attempt will be made to correlate the recorded frequency of gate vibration with the natural period of vibration of the gate and hoist mechanism.

Air Demand

26. The equipment and methods for measuring air demand have been previously described in paragraph 12. For type A gate, maximum points of air demand occurred at gate openings of 0.75 ft and 5 ft (plate 22). These gate openings correspond to those for which pressures on the roof of the downstream conduit were most critical (plate 17). For type B gate, air demand gradually increased as the gate was opened, reaching a maximum at 5-ft opening (plate 23). Maximum air demands were 323 and 290 cfs for types A and B gates, respectively. For both gates, air demand gradually reduced to zero between gate openings of 5 and 6 ft as conduit flow changed from partly full to full. Also, for both gates, large air demands occurred at a gate opening of 0.25 ft, which probably results from a combination of spray filling the downstream conduit at small gate openings and submergence of the conduit exit by high tailwater during small conduit flows. The spray action causes maximum air entrainment and the submerged exit prevents part of the air demand from being supplied at the conduit exit.

27. In analyzing the air demand data, it should be noted, as stated

in paragraph 14, that a reduction in orifice size does not result in a similar reduction in air vent size. Air demand data would be most useful if the quantity of air could be related to a vent of uniform size. The recorded data, together with air vent and orifice sizes, will be analyzed further with a view to relating air demand and vent size. If this is successful, the relationship will be presented in the final report.

Effect of Air Demand on Gate Performance

28. The effect of throttling the air supply downstream from the gate is shown by the pressure and vibration data referred to previously. Reductions in air supply, within the limits tested, resulted in only small reductions in pressures on the two gates tested and in the downstream conduit. In general, vibration of both gates in the vertical and horizontal planes increased with reduced air supply, the effect being more pronounced for type A gate. Vibration of type A gate with the 25 per cent orifice installed indicated that further reduction in air demand would be undesirable if not unsafe.

Strain Measurements

29. An attempt was made by the Structural Branch, Little Rock District, to analyze the strain gage measurements to evaluate stresses in the structural members near the bottom of type A gate. Strain gage measurements were not obtained for type B gate and only a limited number of measurements were obtained for type A gate because of trouble experienced with condensation inside the watertight chamber and consequent shorting of the electrical strain gages. The initial data procured at location A

in the type A gate (plate 8) indicated comparative stresses about as expected. They were 50 per cent higher than the stress calculated for the static water load which indicates a considerable impact factor. Data procured during a check run, however, indicated compressive stresses nearly twice as large as for the initial test. Pressure data for location B were erratic and did not give definite results. Since no strain gage results were obtained for type B gate nor for the lower part of type A gate (locations C and D), and the results obtained could not be analyzed to present dependable data, none of the results have been included in this report.

PART IV: CONCLUSIONS

30. On the basis of a preliminary analysis of the test results presented in previous paragraphs, the following conclusions appear justified:

- a. The over-all hydraulic performance of type B gate (45-degree lip shape) was far superior to type A gate (flat-bottom, existing Norfork gate) at partial gate openings.
- b. Based on the pressure data, hydraulic downpull of considerable magnitude occurred on the bottom of type A gate and hydraulic uplift occurred on the bottom of type B gate. (Total gate loads are increased and decreased by hydraulic downpull and uplift, respectively.)
- c. Instantaneous pressure fluctuations were considerably smaller in magnitude for type B gate.
- d. Cavitation probably occurred 100 per cent of the time on the bottom of type A gate for most gate openings, whereas cavitation did not occur on the bottom of type B gate.
- e. Vibrations in the vertical direction were comparatively small for both gates, being somewhat smaller for type B gate. Vibration magnitudes in the horizontal direction (upstream and downstream) for type A gate were approximately five times the corresponding magnitudes for type B gate. (The large horizontal vibration of type A gate is attributed to the unstable pressures on the bottom of the gate.)
- f. Air demand was greater for type A gate, probably as a result of low pressures on the gate bottom and rougher flow conditions under the gate. Although air demand varied considerably with gate opening for both gates, in general type B gate required less air and the air demand varied more uniformly with gate opening.
- g. In general, negative pressures in the conduit downstream of the gate were increased when the air supply was reduced.
- h. Downward hydraulic loads on top of type A gate, as indicated by bonnet pressures, were small (7 to 21 per cent of the head on the gate) for gate openings of 0.5 ft or greater, when the top of gate was not in contact with the downstream seal.

TABLES

Table 1

PIEZOMETER ELEVATIONS -- TYPE A GATE

Pie- zometer Number	Gate Opening in Feet							
	0.25	0.50	1.0	2.0	3.0	4.0	5.0	6.0
1	390.6	390.8	391.3	392.3	393.3	394.3	395.3	396.3*
2	390.5	390.7	391.2	392.2	393.2	394.2	395.2	396.2
3	390.1	390.7	391.2	392.2	393.2	394.2	395.2	396.2
4	390.4	390.7	391.2	392.2	393.2	394.2	395.2	396.2
5	390.4	390.7	391.2	392.2	393.2	394.2	395.2	396.2
6	390.4	390.6	391.1	392.1	393.1	394.1	395.1	396.1
7	390.4	390.6	391.1	392.1	393.1	394.1	395.1	396.1
8	390.4	390.6	391.1	392.1	393.1	394.1	395.1	396.1
9	390.6	390.8	391.3	392.3	393.3	394.3	395.3	396.3*
10	390.4	390.7	391.2	392.2	393.2	394.2	395.2	396.2
11	390.4	390.7	391.2	392.2	393.2	394.2	395.2	396.2
12	390.4	390.6	391.1	392.1	393.1	394.1	395.1	396.1
13	390.4	390.6	391.1	392.1	393.1	394.1	395.1	396.1

NOTES: Piezometer locations are shown on plate 5.
 All piezometers marked by asterisk (*) are located in the gate well for particular opening indicated.

Table 2

PRESSURE DATA -- TYPE A GATE
Air Vent Unrestricted

Piez Number	Gate Opening in Feet							
	0.25	0.50	1.0	2.0	3.0	4.0	5.0	6.0
1	130.6 -----	95.8 97.4	71.3 71.1	53.1 53.1	48.1 48.5	61.7 59.3	80.3 75.5	21.4* -----
2	58.7 -----	-6.0 -10.5	-7.2 -10.5	-7.7 -9.1	-9.2 -12.0	-10.3 -3.9	-12.4 0.8	76.7 -----
3	40.5 -----	-9.2 -10.6	-7.8 -10.6	-8.9 -9.7	-10.1 -11.9	-8.2 -10.7	-9.5 -11.0	19.6 -----
4	75.8 -----	-10.7 -10.1	-7.1 -10.2	-7.8 -10.2	-8.7 -11.7	-6.3 -7.6	-7.3 -8.0	29.6 -----
5	100.3 -----	51.5 63.3	-5.4 -10.5	-8.4 -9.0	-7.4 -9.2	-5.2 -6.3	-7.3 -8.2	50.8 -----
6	-9.9 -----	-3.9 -8.6	0.0 -3.3	-2.0 -2.1	-2.4 -3.9	3.9 0.9	0.1 0.7	-8.3 -----
7	-9.9 -----	9.4 19.4	-2.4 -8.9	-7.0 -7.3	-7.5 -8.9	-3.7 -6.3	-6.5 -7.2	-12.2 -----
8	14.1 -----	1.0 11.3	-0.1 -1.6	-4.3 -4.7	-5.4 -5.8	-2.9 4.2	-5.2 -5.5	17.4 -----
9	122.2 -----	69.1 48.1	42.0 42.5	20.6 24.0	19.2 20.5	28.3 30.6	46.0 45.8	14.2* -----
10	29.9 -----	-9.7 -10.4	-8.3 -10.2	-10.8 -11.1	-11.2 -12.3	-11.4 -11.8	-13.5 -14.3	53.0 -----
11	82.9 -----	-10.1 -10.2	-8.3 -10.7	-8.8 -11.6	-9.8 -12.3	-9.7 -11.1	-11.5 -14.0	50.8 -----
12	34.2 -----	-10.1 -10.2	30.6 44.2	-7.7 -11.6	-9.0 -12.4	-8.5 -9.4	8.6 6.9	-12.8 -----
13	40.2 -----	6.6 11.4	-6.7 -5.6	3.0 2.5	-1.4 -0.9	2.4 -2.5	-5.0 -5.1	18.2 -----

NOTES: Piezometer locations are shown on plate 5. Piezometer zeros are shown in table 1. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl. All piezometers marked by asterisk (*) are located in gate well for particular opening indicated.

Table 3

PRESSURE DATA -- TYPE A GATE
Air Vent Restricted By 75 Per Cent Orifice

Piez Number	Gate Opening in Feet						
	<u>0.25</u>	<u>0.50</u>	<u>1.0</u>	<u>2.0</u>	<u>3.0</u>	<u>4.0</u>	<u>5.0</u>
1	131.5	96.3	70.8	52.6	48.9	60.6	84.4
2	55.6	-8.8	-7.9	-9.2	-10.8	-11.1	-12.5
3	37.7	-9.4	-8.4	-9.9	-12.3	-8.5	-10.6
4	73.1	-8.5	-7.6	-8.1	-10.7	-5.7	-8.7
5	98.7	55.0	-4.6	-7.2	-8.4	-5.7	-8.5
6	-8.2	-4.5	-2.9	-2.6	-3.6	4.3	1.2
7	-8.2	18.7	-3.0	-6.5	-8.4	-3.8	-6.6
8	12.0	10.2	-0.3	-4.8	-6.7	-3.0	-6.6
9	119.2	67.2	42.1	22.5	20.0	26.7	45.1
10	26.0	-7.9	-8.5	-9.4	-10.4	-10.9	-11.9
11	79.4	-8.8	-9.9	-10.4	-10.5	-11.4	-12.0
12	36.0	-7.8	37.2	-9.0	-9.2	-9.5	-8.2
13	41.0	3.6	-7.7	0.2	-2.7	-0.9	-5.3

NOTES: Piezometer locations are shown on plate 5. Piezometer zeros are shown in table 1. Pressures are recorded in feet of water. Reservoir elevation 550.0 msl.

Table 4

PRESSURE DATA -- TYPE A GATE
Air Vent Restricted By 50 Per Cent Orifice

Piez Number	Gate Opening in Feet						
	0.25	0.50	1.0	2.0	3.0	4.0	5.0
1	131.5	96.1	71.5	54.2	48.8	61.1	79.4
	-----	97.0	70.8	52.5	48.8	61.6	80.0
2	58.1	-7.9	-8.6	-9.8	-11.9	-13.4	-13.2
	-----	-10.0	-10.7	-10.6	-12.5	-10.9	-12.8
3	39.3	-9.2	-9.8	-11.2	-12.1	-6.1	-12.6
	-----	-10.4	-10.6	-11.3	-12.5	-9.3	-9.3
4	73.6	-10.1	-9.2	-10.0	-12.2	-5.2	-10.2
	-----	-10.4	-10.5	-10.8	-12.1	-7.6	-9.7
5	99.4	59.3	-4.3	-9.0	-11.9	-4.3	-9.1
	-----	64.0	-7.2	-10.0	-9.5	-6.9	-8.5
6	-9.3	-8.2	0.0	-3.1	-3.1	3.9	-0.3
	-----	-9.2	-5.1	-2.0	-2.4	3.9	0.3
7	-9.5	19.7	-3.6	-6.5	-9.2	-3.2	-6.9
	-----	13.3	-5.9	-7.0	-8.7	-3.8	-7.2
8	12.5	10.9	-1.1	-5.1	-7.1	-3.2	-6.9
	-----	11.5	-2.1	-4.8	-6.2	-3.3	-7.2
9	121.4	68.8	41.4	24.0	19.6	26.2	44.4
	-----	70.1	41.6	23.2	20.2	28.0	46.6
10	29.3	-10.0	-9.0	-10.8	-11.7	-13.6	-9.3
	-----	-10.5	-10.0	-11.5	-11.4	-12.8	-12.7
11	81.5	-10.2	-10.2	-11.2	-11.7	-12.8	-13.6
	-----	-10.4	-10.3	-11.9	-12.4	-11.7	-13.6
12	37.9	-10.2	37.9	-10.4	-11.0	-9.9	11.5
	-----	-10.4	39.7	-11.7	-11.1	-9.4	-10.9
13	40.9	5.5	-5.8	-0.3	-2.7	-0.6	-6.6
	-----	11.1	-5.5	3.2	-2.9	-1.4	-6.6

NOTES: Piezometer locations are shown on plate 5. Piezometer zeros are shown in table 1. Pressures are recorded in feet of water. Reservoir elevation 550.0 msl.

Table 5

PRESSURE DATA -- TYPE A GATE
Air Vent Restricted By 25 Per Cent Orifice

Piez Number	Gate Opening in Feet							
	0.25	0.50	1.0	2.0	3.0	4.0	5.0	6.0
1	131.0 -----	96.6 97.7	71.3 70.7	53.7 52.4	48.7 47.2	61.7 56.8	80.1 84.7	21.7* -----
2	58.3 -----	-10.4 -10.0	-10.7 -10.6	-11.8 -11.2	-12.6 -12.5	-11.1 -11.4	-10.5 -10.7	78.4 -----
3	39.9 -----	-10.6 -10.5	-10.9 -11.0	-11.7 -11.7	-12.7 -12.6	-11.0 -11.6	-12.4 -12.4	18.7 -----
4	73.9 -----	-10.6 -10.5	-10.6 -10.7	-11.8 -11.6	-12.4 -12.6	-9.9 -11.9	-10.7 -10.2	30.3 -----
5	99.5 -----	56.6 63.6	-8.6 -10.5	-10.7 -10.8	-11.3 -11.7	-8.5 -10.0	-8.9 -10.4	55.0 -----
6	-9.9 -----	-8.3 -8.6	-2.1 -5.1	-2.5 -3.9	-2.9 -2.9	-3.7 -0.8	-2.7 -1.5	-10.0 -----
7	-10.0 -----	19.5 13.7	-5.9 -7.2	-7.9 -8.3	-8.9 -9.1	-7.4 -6.5	-8.7 -9.2	-8.4 -----
8	12.2 -----	10.5 11.3	-0.3 -0.8	-4.1 -4.6	-7.1 -6.5	-5.7 -5.2	-8.7 -9.2	14.8 -----
9	120.2 -----	67.8 69.5	41.4 42.0	23.1 24.2	21.0 20.9	28.5 28.2	42.7 46.7	14.0* -----
10	28.1 -----	-10.5 -10.2	-10.6 -10.6	-11.7 -11.2	-12.7 -12.6	-11.9 -12.7	-12.7 -13.5	52.9 -----
11	81.0 -----	-11.1 -10.4	-10.6 -10.9	-11.7 -11.7	-12.7 -12.6	-11.9 -12.7	-11.6 -14.1	51.7 -----
12	37.4 -----	-10.3 -10.3	42.2 39.7	-11.9 -11.7	-12.7 -12.6	-9.7 -11.5	4.6 -11.8	-6.0 -----
13	41.1 -----	4.0 -10.6	-4.7 -3.5	-0.1 2.3	-2.2 -2.1	-1.2 -2.0	-8.4 -8.7	18.1 -----

NOTES: Piezometer locations are shown on plate 5. Piezometer zeros are shown in table 1. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl. All piezometers marked by asterisk (*) are located in the gate well for particular opening indicated.

Table 6

PIEZOMETER ELEVATIONS -- TYPE B GATE

Pie- zometer Number	Gate Opening in Feet							
	0.25	0.50	1.0	2.0	3.0	4.0	5.0	6.0
1	391.8	392.0	392.5	393.5	394.5	395.5	396.5*	397.5*
2	391.4	391.6	392.1	393.1	394.1	395.1	396.1	397.1*
3	391.0	391.3	391.8	392.8	393.8	394.8	395.8	396.8*
4	390.9	391.1	391.6	392.6	393.6	394.6	395.6	396.6*
5	390.7	390.9	391.4	392.4	393.4	394.4	395.4	396.4*
6	390.5	390.8	391.3	392.3	393.3	394.3	395.3	396.3*
7	390.4	390.7	391.2	392.2	393.2	394.2	395.2	396.2
8	391.7	392.0	392.5	393.5	394.5	395.5	396.5*	397.5*
9	391.3	391.5	392.0	393.0	394.0	395.0	396.0	397.0*
10	390.9	391.1	391.6	392.6	393.6	394.6	395.6	396.6*
11	390.4	390.7	391.2	392.2	393.2	394.2	395.2	396.2

NOTES: Piezometer locations shown on plate 7.
 All piezometers marked by asterisk (*) are located in the gate well for particular opening indicated.

Table 7

PRESSURE DATA -- TYPE B GATE
Air Vent Unrestricted

Piez Number	Gate Opening in Feet							
	0.25	0.50	1.0	2.0	3.0	4.0	5.0	6.0
1	158.0	152.9	143.4	130.8	124.1	131.2	34.4*	14.9*
	156.4	152.5	142.7	132.2	130.1	140.6	39.8	0.1
2	153.8	143.8	123.2	101.5	88.6	101.9	123.7	27.6*
	153.6	142.2	123.0	101.3	93.4	105.2	129.2	8.5*
3	153.9	139.8	111.4	94.8	83.0	84.7	103.6	9.9*
	151.6	137.2	120.9	95.0	83.6	86.4	103.3	-1.0*
4	148.3	134.6	119.5	97.7	85.9	85.8	95.3	11.5*
	148.1	133.7	119.0	96.5	86.2	85.8	94.8	0.8*
5	142.5	127.0	114.2	96.8	87.4	85.3	88.9	52.1*
	142.3	126.5	113.8	95.6	87.2	85.1	88.2	25.7*
6	138.9	128.1	121.9	111.2	107.4	105.6	97.8	89.7*
	138.5	127.2	121.9	109.9	105.6	103.6	99.3	40.1*
7	-2.7	-0.2	-1.1	-1.8	-1.7	0.4	-3.0	-12.8
	-2.6	0.2	-1.2	-2.1	-2.2	-1.8	-3.3	-13.7
8	153.9	146.3	129.6	115.2	112.6	117.8	107.9*	19.0*
	153.9	145.4	129.8	115.4	114.0	119.9	109.0*	4.9*
9	147.0	126.2	98.2	60.1	53.4	59.2	85.9	15.4*
	147.0	125.9	98.2	59.8	51.8	61.8	88.5	0.8*
10	141.6	120.9	92.5	64.1	54.8	48.9	50.8	13.0*
	141.4	117.3	93.7	63.0	55.0	50.2	52.7	1.3*
11	-8.3	17.9	10.6	-7.1	-11.0	27.7	20.9*	-7.2
	-----	11.3	0.1	1.3	-1.7	30.5	22.3*	-11.9

NOTES: Piezometer locations shown on plate 7. Piezometer zeros are shown in table 6. Pressures are recorded in feet of water. Reservoir elevation 550.4 msl. All piezometers marked by asterisk (*) are located in the gate well for particular opening indicated.

Table 8

PRESSURE DATA -- TYPE B GATE
Air Vent Restricted By 75 Per Cent Orifice

Piez Number	Gate Opening in Feet						
	0.25	0.50	1.0	2.0	3.0	4.0	5.0
1	136.5	151.1	142.0	131.1	129.9	137.4	27.5*
	-----	150.8	142.9	130.2	-----	136.2	31.6*
2	133.1	142.2	139.0	101.5	94.2	106.1	129.4
	-----	142.2	128.1	101.3	-----	107.9	116.7
3	129.6	137.2	120.8	94.5	84.2	85.5	105.6
	-----	137.0	120.9	94.5	-----	87.2	103.8
4	127.1	133.5	118.8	96.4	86.2	85.6	96.9
	-----	133.3	119.0	96.5	-----	85.8	105.4
5	120.1	130.8	113.4	95.6	87.1	84.7	89.6
	-----	131.2	113.7	95.4	-----	84.5	88.2
6	117.3	127.4	121.6	110.2	105.6	103.8	101.2
	-----	127.4	121.7	111.4	-----	103.8	97.5
7	-3.1	-1.1	-1.4	-3.8	-1.8	-2.0	-3.3
	-----	-0.8	-1.4	-3.9	-----	-2.0	-3.7
8	134.2	144.2	129.1	115.3	111.6	114.9	102.9*
	-----	146.0	130.8	115.6	-----	117.3	105.9*
9	126.4	129.9	98.3	58.7	49.7	61.4	84.6
	-----	130.4	99.8	60.5	-----	61.3	86.8
10	120.6	121.0	92.8	62.5	51.9	49.2	50.7
	-----	121.8	94.8	64.2	-----	49.3	50.5

NOTES: Piezometer locations shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.1 msl. All piezometers marked by asterisk (*) are located in the gate well for particular opening indicated.

Table 9

PRESSURE DATA -- TYPE B GATE
Air Vent Restricted By 50 Per Cent Orifice

Piez Number	Gate Opening in Feet						
	0.25	0.50	1.0	2.0	3.0	4.0	5.0
1	156.2	152.5	143.4	129.0	128.9	135.7	40.5*
	-----	152.7	143.2	130.6	129.9	132.1	35.7*
2	153.6	142.5	123.7	103.0	93.4	104.0	115.9
	-----	143.3	128.2	101.9	95.3	107.2	121.1
3	150.2	137.0	121.2	95.2	83.7	86.0	100.2
	-----	137.7	121.2	94.8	84.2	87.3	101.6
4	147.6	133.5	119.1	96.1	86.1	85.7	93.0
	-----	135.6	119.2	96.6	86.2	85.9	93.6
5	141.6	126.3	113.6	95.1	86.5	85.5	87.5
	-----	126.5	113.8	95.3	86.9	84.9	88.2
6	143.1	127.1	121.6	110.3	105.2	104.6	98.7
	-----	127.1	126.5	110.8	105.8	103.8	100.3
7	-3.1	-0.3	-1.4	-1.6	-2.0	-2.3	-4.2
	-----	-0.3	-1.4	-1.5	-1.5	-1.9	-4.2
8	153.9	145.4	129.8	117.9	112.8	119.1	106.8*
	-----	145.8	131.2	115.9	113.5	121.1	104.8*
9	146.8	125.7	97.7	60.5	54.9	60.1	85.4
	-----	125.7	99.1	60.9	52.3	61.8	87.3
10	140.3	120.7	93.0	64.1	53.0	49.2	50.7
	-----	121.7	94.4	63.8	54.1	49.5	50.8
11	10.3	11.4	1.1	8.5	-9.7	23.6	114.2
	-----	12.4	6.2	-0.8	-3.5	24.0	11.9

NOTES: Piezometer locations are shown on plate 7. Piezometer zeros are shown in table 6. Pressures are recorded in feet of water. Reservoir elevation 550.1 msl. All piezometers marked by asterisk (*) are located in gate well for particular opening indicated.

Table 10

PRESSURE DATA -- TYPE B GATE
Air Vent Restricted By 25 Per Cent Orifice

Piez Number	Gate Opening in Feet						
	0.25	0.50	1.0	2.0	3.0	4.0	5.0
1	156.2 -----	151.8 151.6	143.2 142.9	130.2 130.4	130.3 129.9	138.3 135.6	32.1* 27.9*
2	153.3 -----	142.5 142.5	128.2 128.4	101.1 101.5	92.8 94.2	110.5 106.5	121.0 124.3
3	150.2 -----	137.0 137.2	121.0 121.3	94.4 94.7	83.0 83.4	86.3 86.7	102.6 103.0
4	147.6 -----	133.5 133.3	119.1 119.1	96.4 96.5	85.9 86.1	85.6 85.8	94.2 94.2
5	141.3 -----	131.0 131.2	113.7 114.0	95.4 95.4	86.5 87.0	84.6 84.7	89.9 86.6
6	142.9 -----	127.4 127.1	122.0 121.9	110.5 110.8	105.9 105.7	104.7 103.5	97.5 98.2
7	-3.5 -----	-0.4 -0.6	-1.4 -1.4	-2.7 -1.3	-2.5 -1.9	-2.5 -2.4	-6.5 -6.4
8	153.5 -----	145.4 145.8	129.6 131.0	115.4 115.4	112.1 112.8	117.7 116.9	105.3* 106.7*
9	147.2 -----	130.2 130.6	97.4 99.4	61.0 60.3	50.9 51.1	61.7 62.4	85.4 84.2
10	142.3 -----	120.7 121.8	93.6 94.5	62.6 63.3	52.1 52.9	49.5 50.1	49.2 49.0
11	-9.8 -----	11.0 15.0	11.7 22.9	-1.6 -6.8	-1.6 -2.4	24.5 27.6	12.7 12.9

NOTES: Piezometer locations shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.1 msl. All piezometers marked by asterisk (*) are located in gate well for particular opening indicated.

Table 11

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 0.25 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1	166.5	144.3	155.5	157.2
2	175.5	151.5	164.0	153.7
3	-----	-----	-----	152.8
4	142.6	133.0	138.0	148.2
5	-----	-----	-----	142.4
6	133.4	126.9	129.9	138.7
7	-12.3	-21.1	-15.9	-2.7
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1	157.1	136.8	146.5	156.2
2	170.3	146.7	156.7	153.3
3	149.3	130.1	139.5	150.2
4	146.7	139.4	143.7	147.6
5	149.2	126.4	137.6	141.3
6	127.3	119.9	123.3	142.9
7	-4.3	-9.5	-6.9	-3.5

NOTE: Pressure cell locations shown on plate 9. Piezometer locations are shown on plate 7. Piezometer zeros shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

Table 12

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 0.5 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1	160.1	137.9	150.0	152.7
2	136.9	118.4	125.2	143.0
3	-----	-----	-----	138.5
4	128.2	117.0	123.0	134.2
5	-----	-----	-----	126.8
6	132.8	124.9	128.9	127.7
7	2.9	-8.3	-2.8	0.0
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1	150.7	131.5	141.0	151.7
2	157.9	136.9	146.7	142.5
3	134.9	114.4	125.3	137.1
4	135.0	121.5	128.5	133.4
5	139.1	111.3	123.3	131.1
6	123.7	114.9	119.3	127.3
7	1.0	-8.1	-4.3	-0.5

NOTE: Pressure cell locations shown on plate 9. Piezometer locations are shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

Table 13

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 1.0 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1	149.2	133.8	139.0	143.1
2	134.7	117.4	121.7	123.1
3	-----	-----	-----	116.2
4	-----	-----	101.4	119.3
5	100.6	90.0	102.1	114.0
6	112.5	102.9	107.8	121.9
7	0.9	-6.6	-2.8	-1.2
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1	142.1	122.9	132.4	143.1
2	140.3	119.4	129.3	128.3
3	110.1	97.9	103.8	121.2
4	118.0	101.6	110.0	119.1
5	119.3	93.2	106.0	113.9
6	113.5	103.9	108.4	122.0
7	-1.6	-6.6	-4.7	-1.4

NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

Table 14

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 2.0 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1	136.6	116.3	127.0	131.5
2	118.6	112.4	115.5	101.4
3	90.9	77.9	84.5	94.9
4	75.9	66.1	71.0	97.1
5	133.5	107.2	119.9	96.2
6	114.9	98.3	106.5	110.6
7	-2.4	-6.9	-4.9	-2.0
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1	133.4	112.4	122.9	130.3
2	107.2	101.0	104.2	101.3
3	86.3	74.4	80.3	94.6
4	90.7	80.0	85.6	96.5
5	97.7	75.2	86.4	95.4
6	110.1	95.3	103.5	110.7
7	-4.0	-7.8	-5.6	-2.0

NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

Table 15

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 3.0 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1	141.7	107.9	125.0	127.1
2	105.0	82.2	100.5	91.0
3	87.9	55.3	71.0	83.3
4	91.5	75.9	83.0	86.1
5	94.7	65.1	79.9	87.3
6	119.9	88.6	104.0	106.5
7	-1.7	-6.4	-4.0	-2.0
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1	132.3	108.1	120.2	130.1
2	101.8	82.6	94.9	93.5
3	74.3	59.1	68.2	83.2
4	86.0	69.6	77.1	86.0
5	94.4	59.2	76.4	86.8
6	122.1	93.8	104.9	105.8
7	-----	-----	-5.6	-2.2

NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

Table 16

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 4.0 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1	147.5	109.9	129.0	135.9
2	115.4	103.6	110.2	103.6
3	86.5	60.1	71.0	85.6
4	97.9	74.3	83.0	85.8
5	97.7	72.2	84.4	85.2
6	108.5	85.0	97.0	104.6
7	-5.9	-11.8	-9.5	-0.7
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1	136.4	106.9	120.8	137.0
2	111.4	92.2	104.4	108.5
3	87.1	57.9	72.7	86.5
4	86.8	66.3	76.2	85.7
5	90.6	59.2	75.2	84.7
6	109.3	79.8	93.2	104.1
7	-4.2	-8.0	-6.2	-2.5

NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

Table 17

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 5.0 Ft

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1*	46.6	15.6	30.4	37.1
2	133.5	115.0	119.2	126.5
3	117.2	88.8	102.5	103.5
4	97.3	79.0	88.0	95.1
5	94.7	72.2	82.9	88.6
6	110.5	83.4	97.0	98.6
7	-6.6	-13.0	-10.1	-3.2
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1*	36.8	7.1	19.8	30.0
2	116.2	102.6	110.0	122.7
3	105.5	77.9	90.3	102.8
4	87.4	73.5	82.8	94.2
5	91.8	58.0	75.6	88.3
6	101.3	71.2	85.5	97.9
7	-6.1	-11.8	-9.4	-6.5

NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.
* Cell located in gate well.

Table 18

PRESSURE CELL DATA -- TYPE B GATE
Gate Open 5.5 Ft

Pressure Cell No.	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1*	-----	-----	-----	-----
2*	-----	-----	-----	-----
3*	-----	-----	-----	-----
4	-----	-----	-----	-----
5	-----	-----	-----	-----
6	-----	-----	-----	-----
7	-----	-----	-----	-----
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1*	44.9	-26.3	33.8	-----
2*	78.2	39.3	61.1	-----
3*	97.7	51.8	75.3	-----
4	119.3	74.1	92.4	-----
5	98.3	59.2	78.6	-----
6	103.5	69.0	85.5	-----
7	-5.9	-11.8	-9.5	-----

NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.
*Cell located in gate well.

Table 19

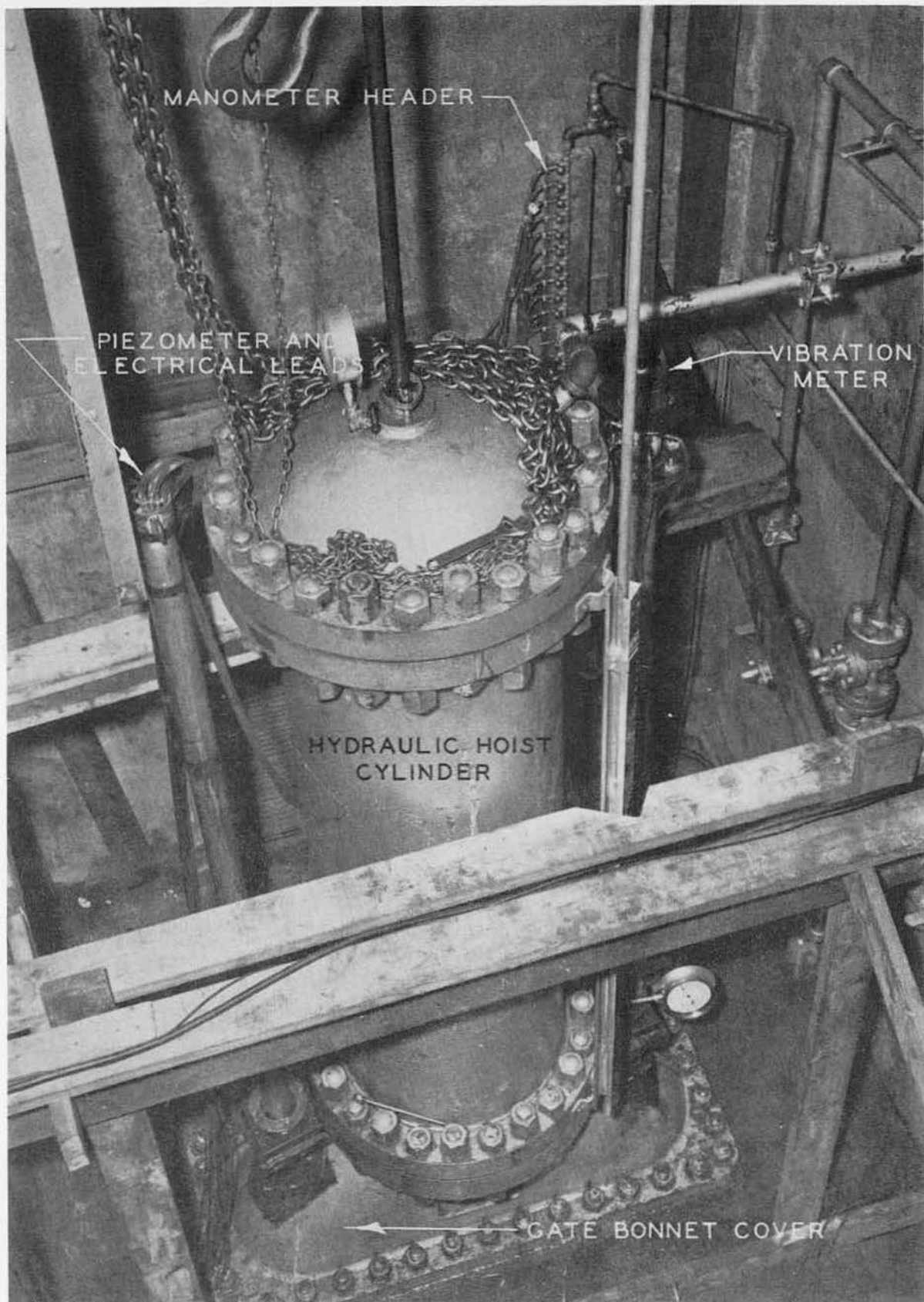
PRESSURE CELL DATA -- TYPE B GATE
Gate Open Full

<u>Pressure Cell No.</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Piezometric Pressure</u>
<u>Air Vent Unrestricted</u>				
1*	16.9	-1.9	8.2	7.5
2*	36.5	12.2	24.0	18.1
3*	90.9	42.6	67.1	4.5
4*	----	----	22.5	6.2
5*	62.2	13.3	38.5	38.9
6*	109.7	47.9	77.7	64.9
7	----	----	----	-13.3
<u>Air Vent Restricted By 25 Per Cent Orifice</u>				
1*	----	----	-20.0	----
2*	60.9	6.8	30.0	----
3*	----	----	-5.4	----
4*	----	----	5.8	----
5*	----	----	60.5	----
6*	----	----	75.4	----
7	12.5	-25.6	-6.3	----

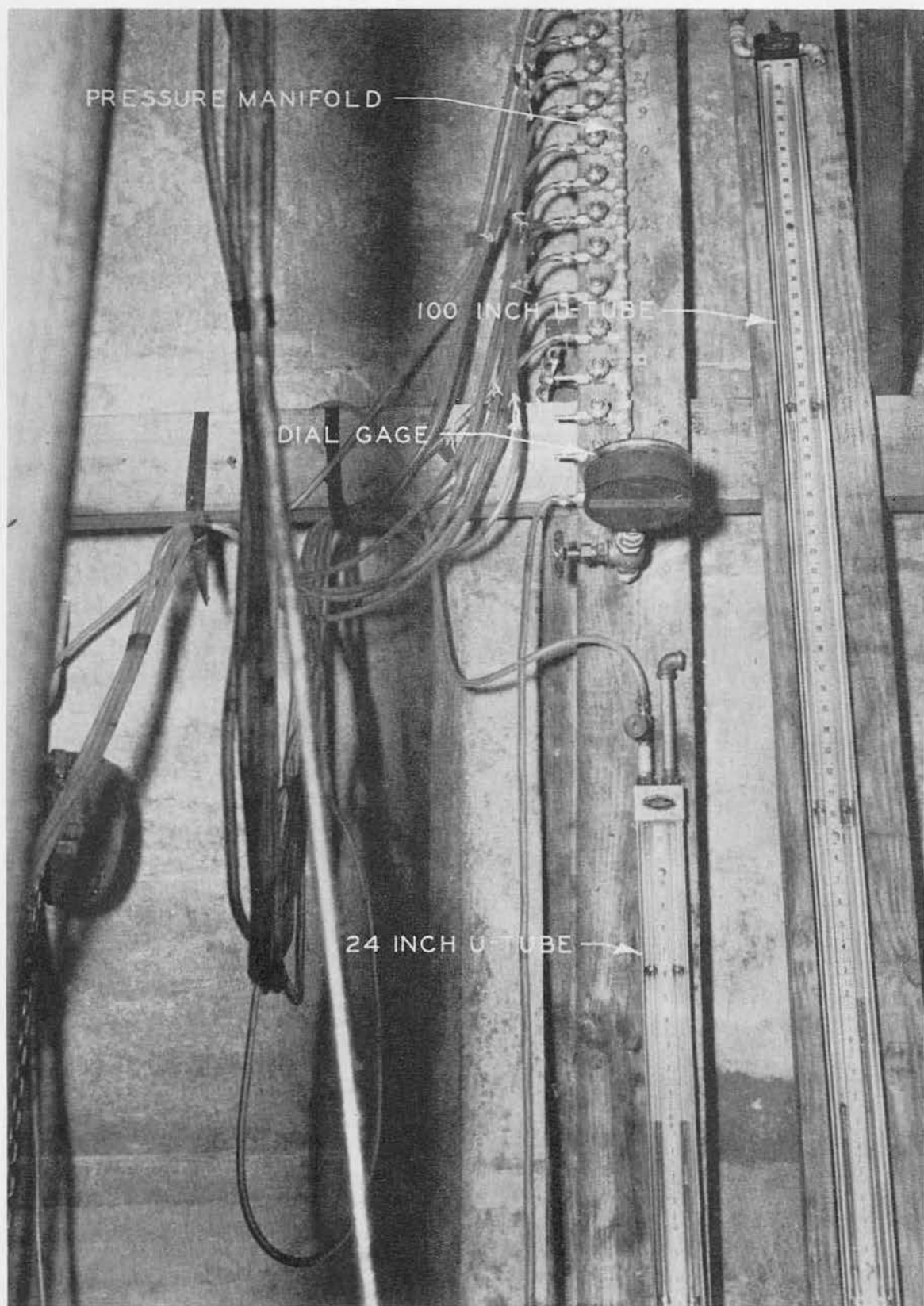
NOTE: Pressure cell locations shown on plate 9. Piezometer locations shown on plate 7. Piezometer zeros are shown on table 6. Pressures are recorded in feet of water. Reservoir elevation 550.2 msl.

* Cell located in gate well.

PHOTOGRAPHS

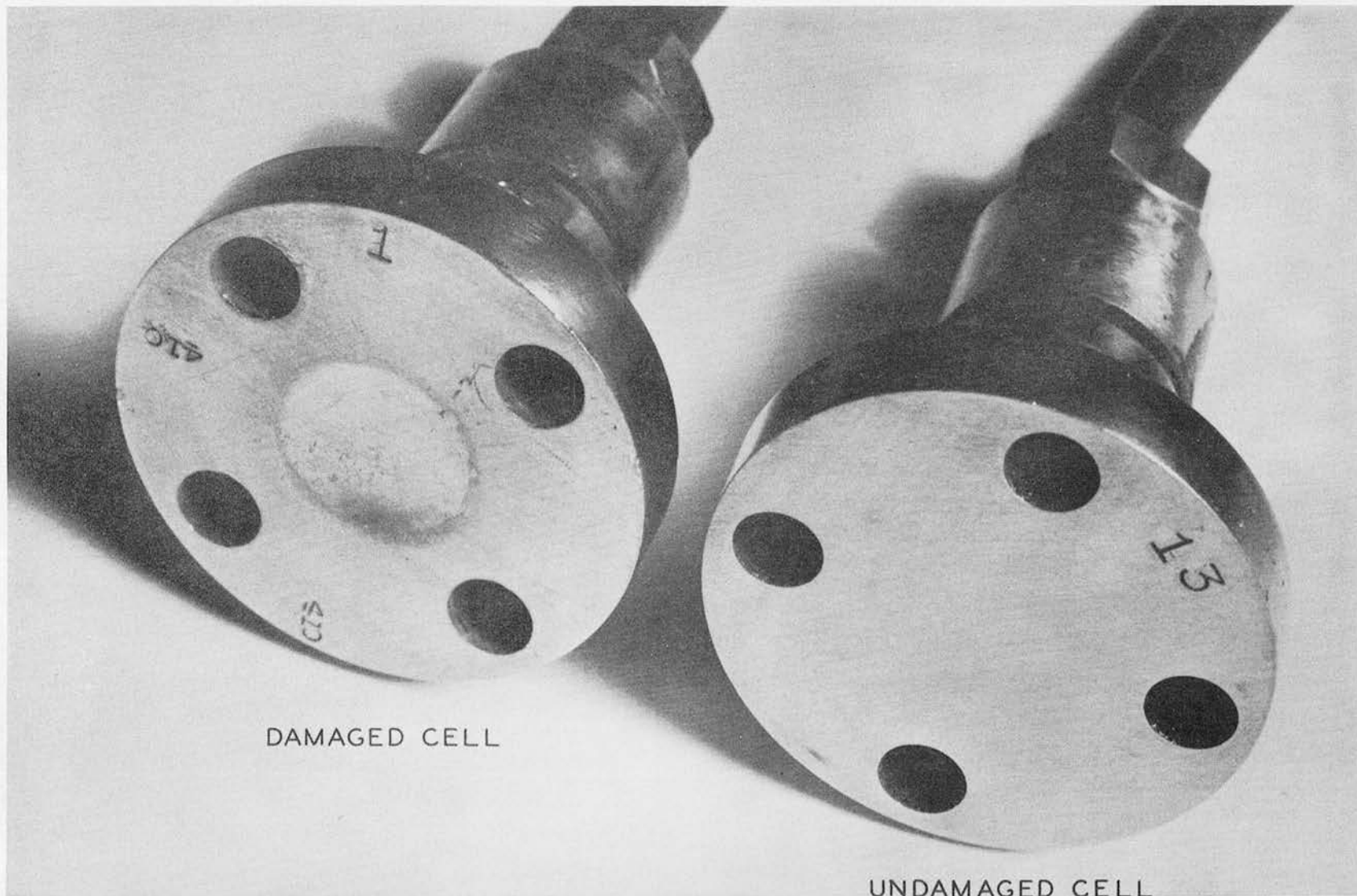


Assembled gate for slide gate tests



Measuring equipment to obtain pressures on front face of slide gate by piezometric method

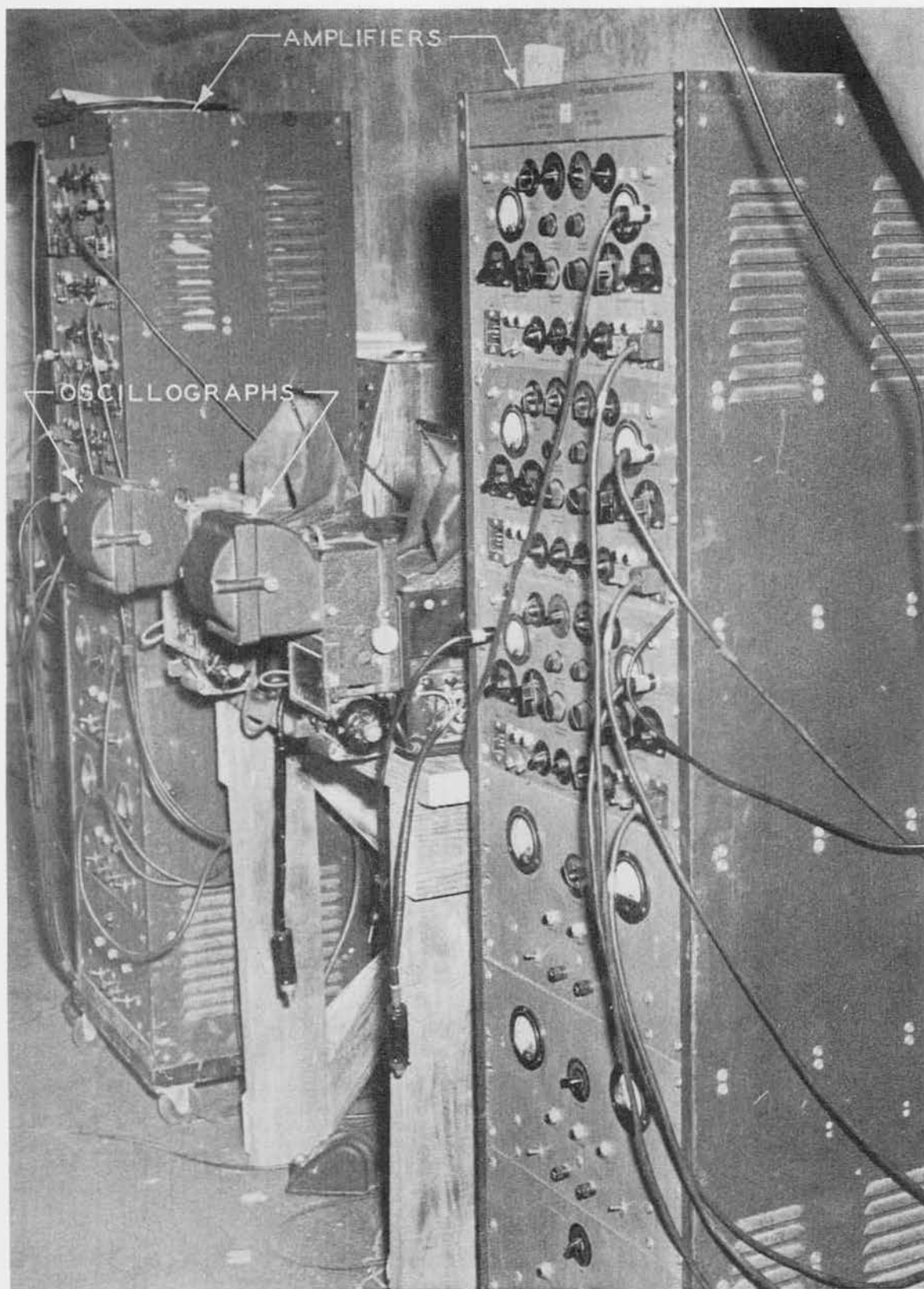
PHOTOGRAPH 2



DAMAGED CELL

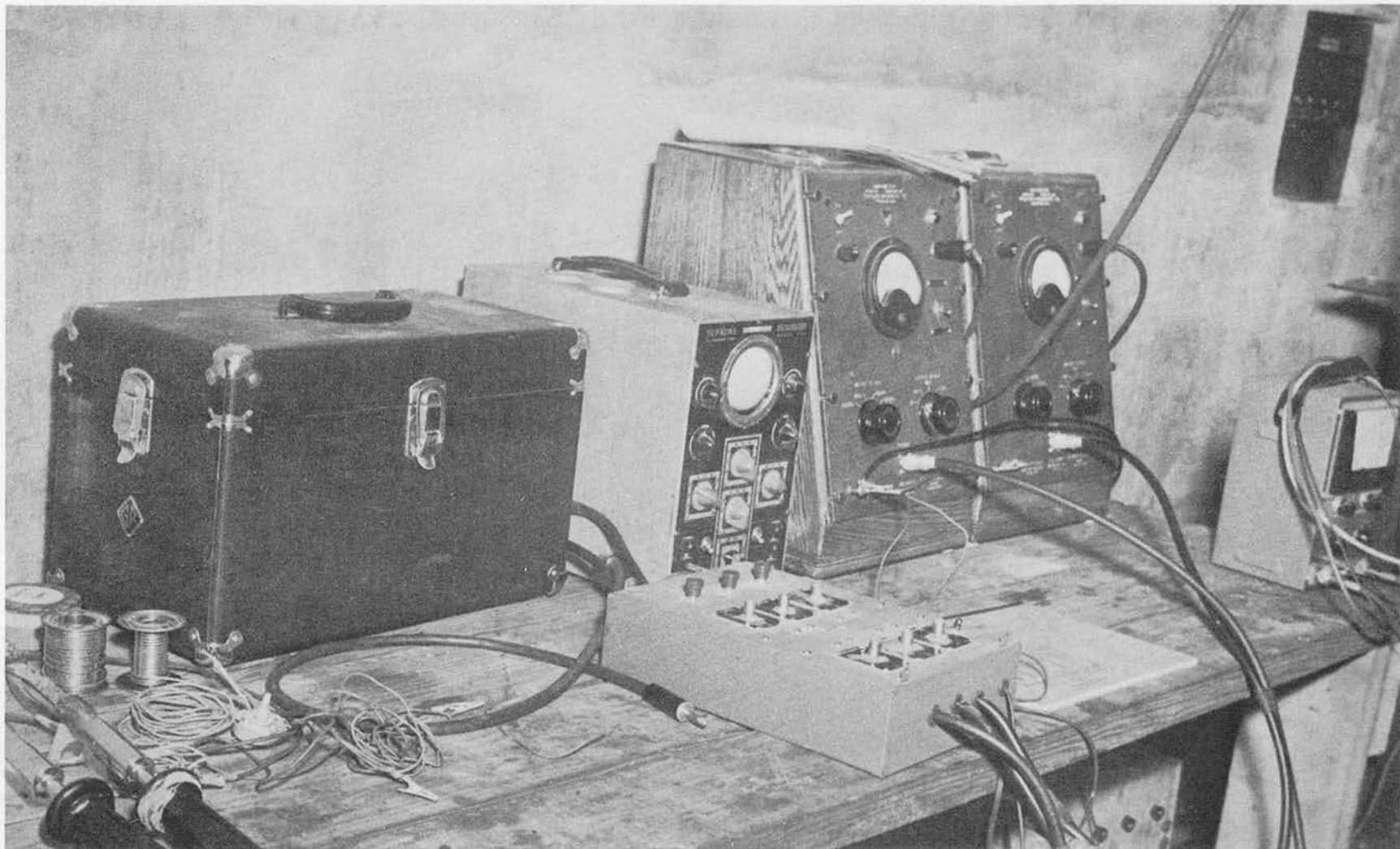
UNDAMAGED CELL

Electrical pressure cells for measuring pressure fluctuations on gate lip



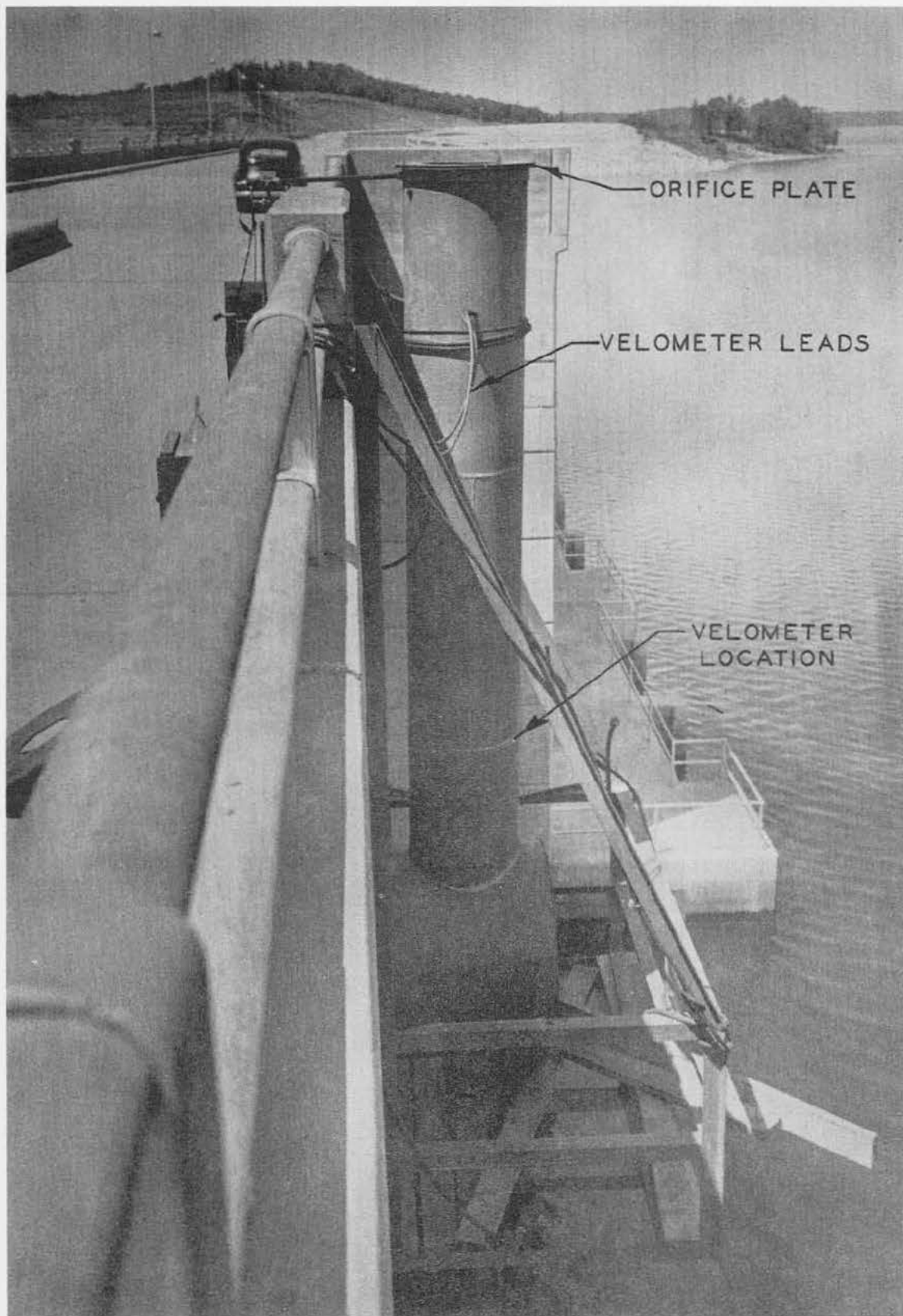
Apparatus for measuring and recording resistance change in SR-4 strain gages (pressure cells). Shown are two 6-channel amplifiers and two Westinghouse type P.A. recording oscillographs

PHOTOGRAPH 4



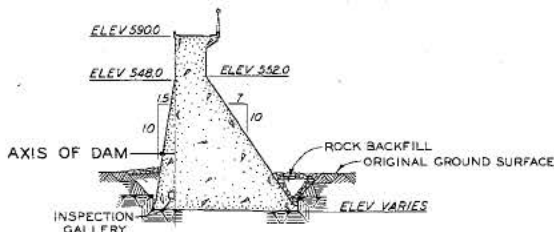
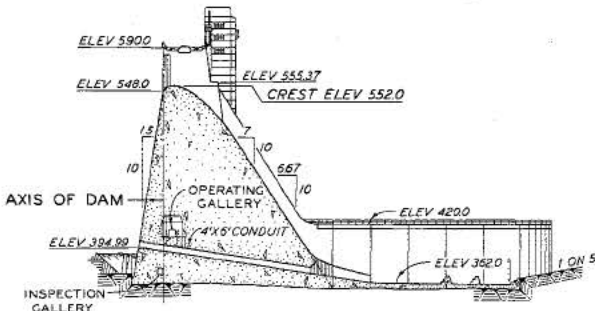
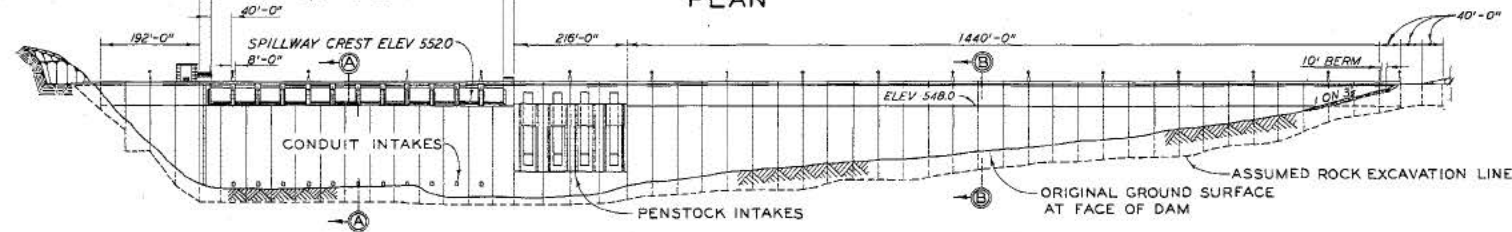
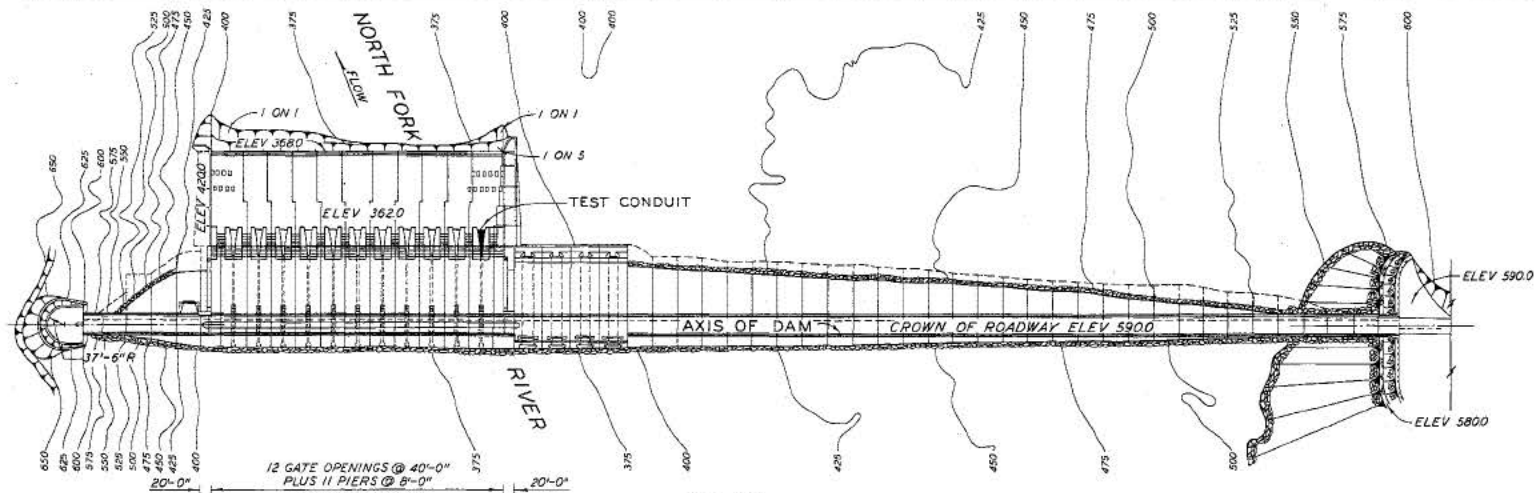
PHOTOGRAPH 5

Apparatus for recording vibration of the test gate. Reading from left to right: general radio vibration analyzer, cathode ray oscilloscope, two televiso's vibrometers. Front row: calibration device for vibrometers and vacuum tube voltmeter

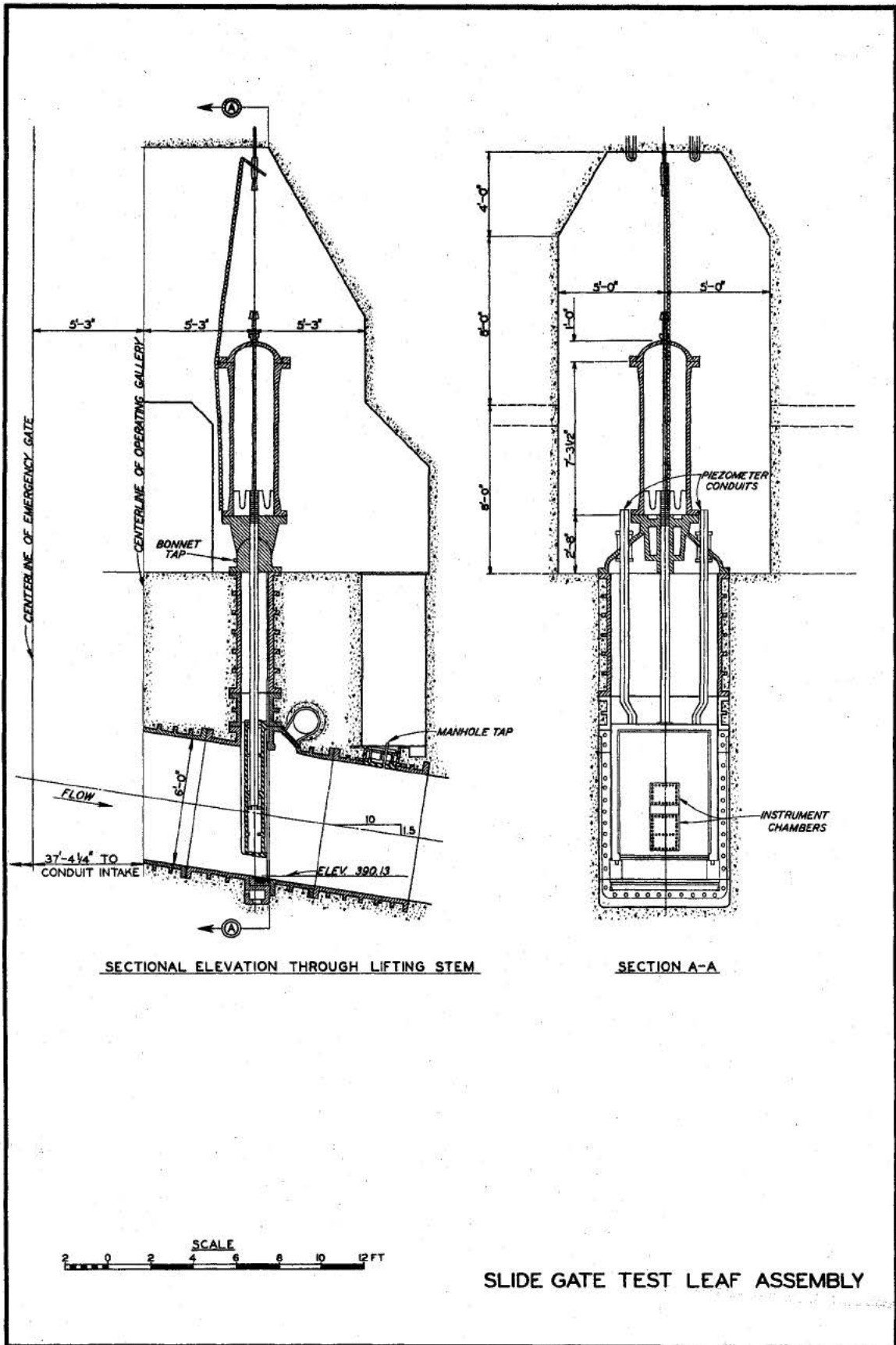


20-in. air vent extension pipe with circular orifice plate installed
PHOTOGRAPH 6

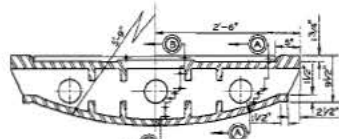
PLATES



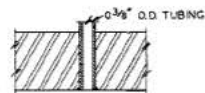
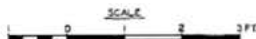
GENERAL DETAILS OF DAM



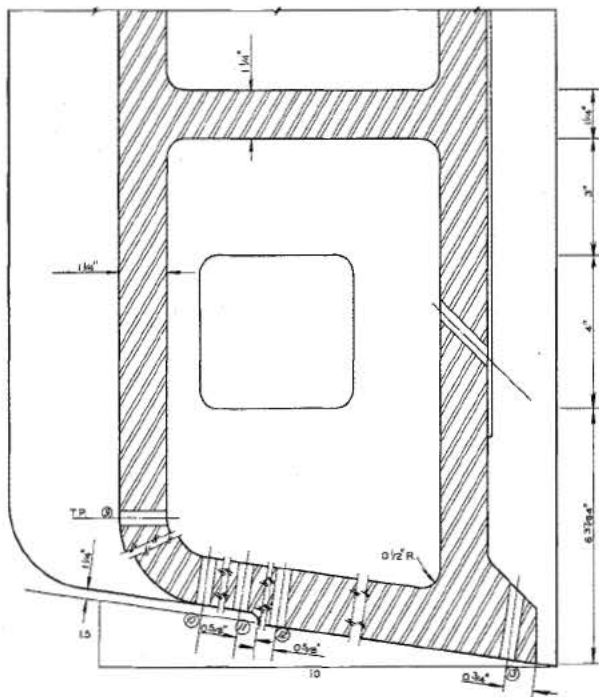
SLIDE GATE TEST LEAF ASSEMBLY



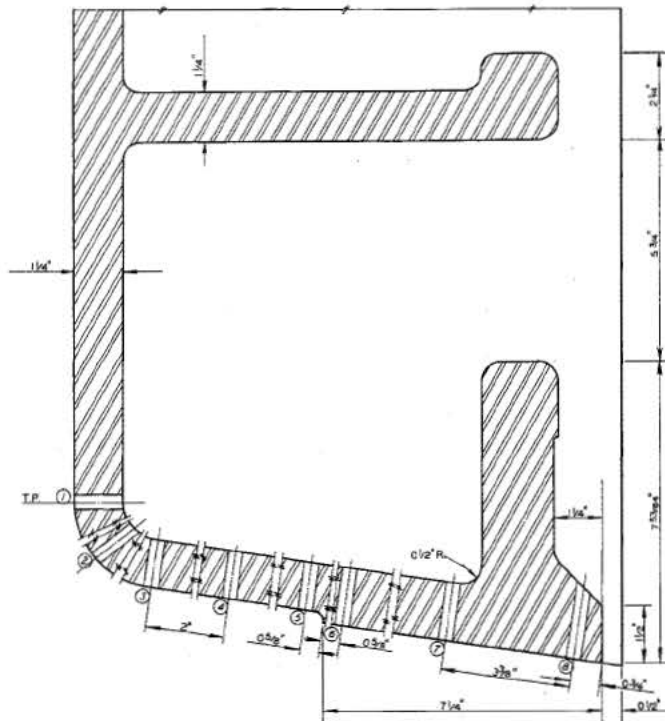
SECTION THROUGH GATE



DETAILS AT PIEZOMETER ORFICE



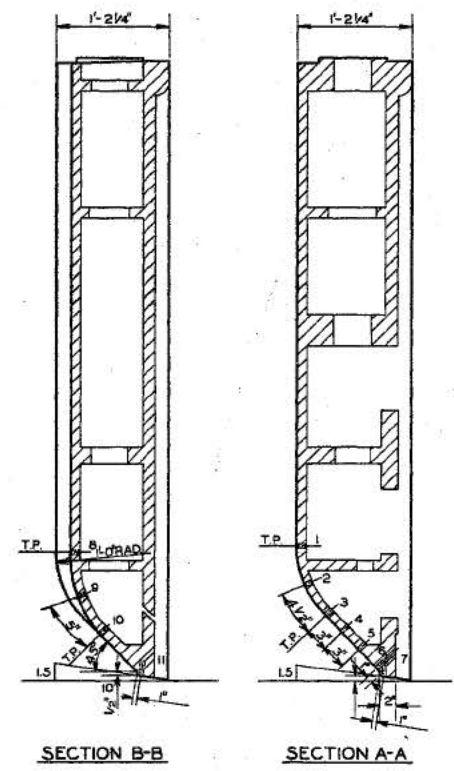
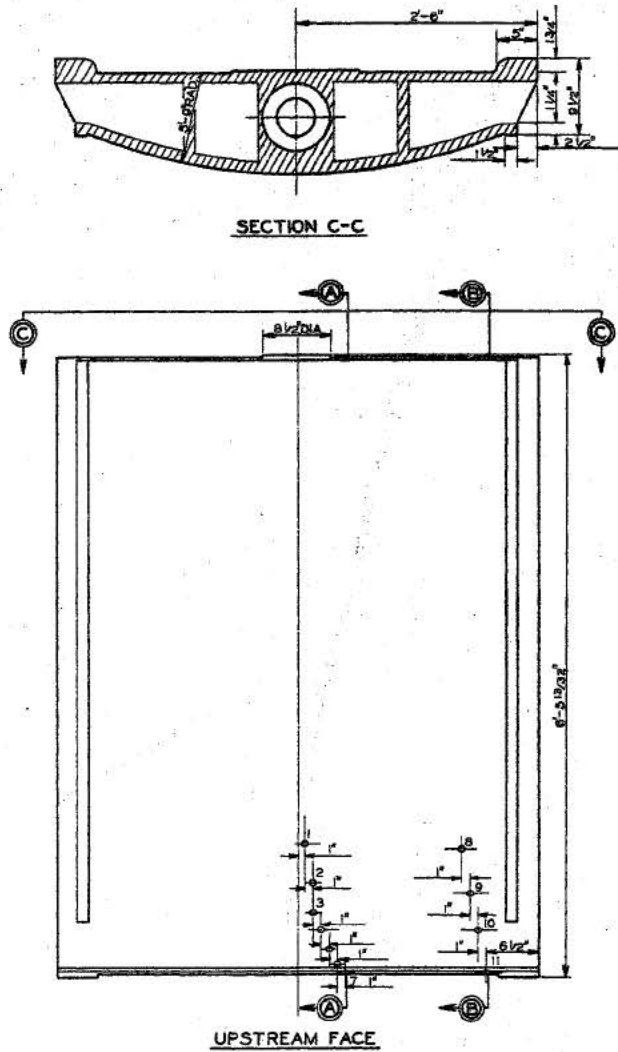
SECTION A-A



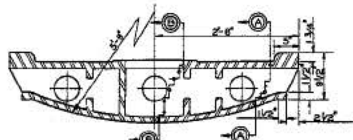
SECTION B-B



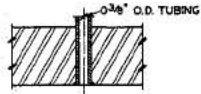
PIEZOMETER LOCATIONS
TYPE A GATE



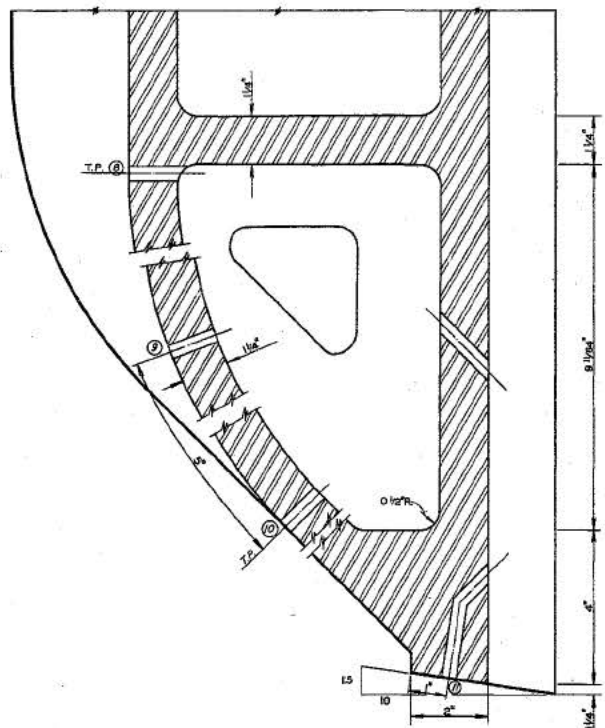
DETAIL OF TYPE B GATE
AND PIEZOMETER LOCATIONS



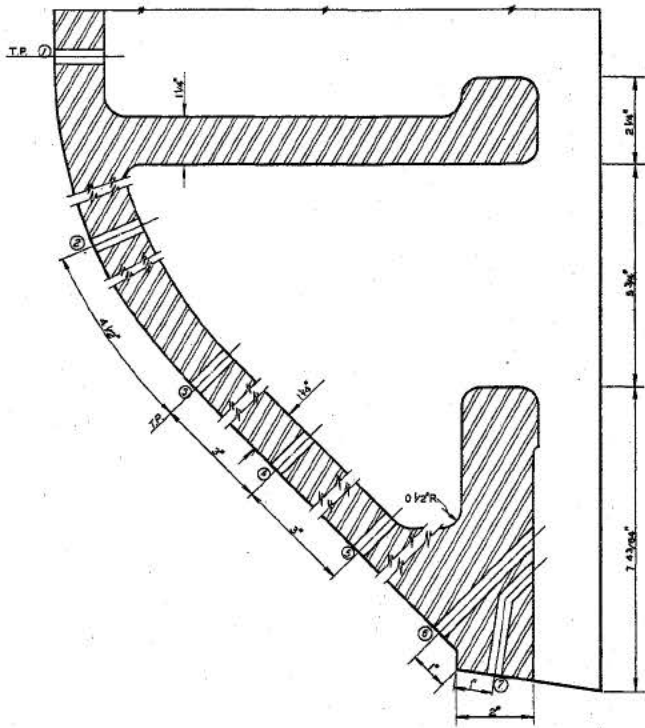
SECTION THROUGH GATE



DETAILS AT PIEZOMETER ORIFICE



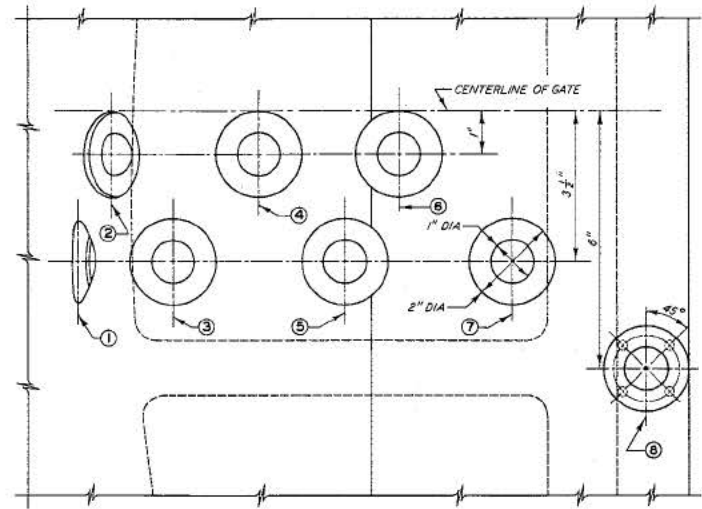
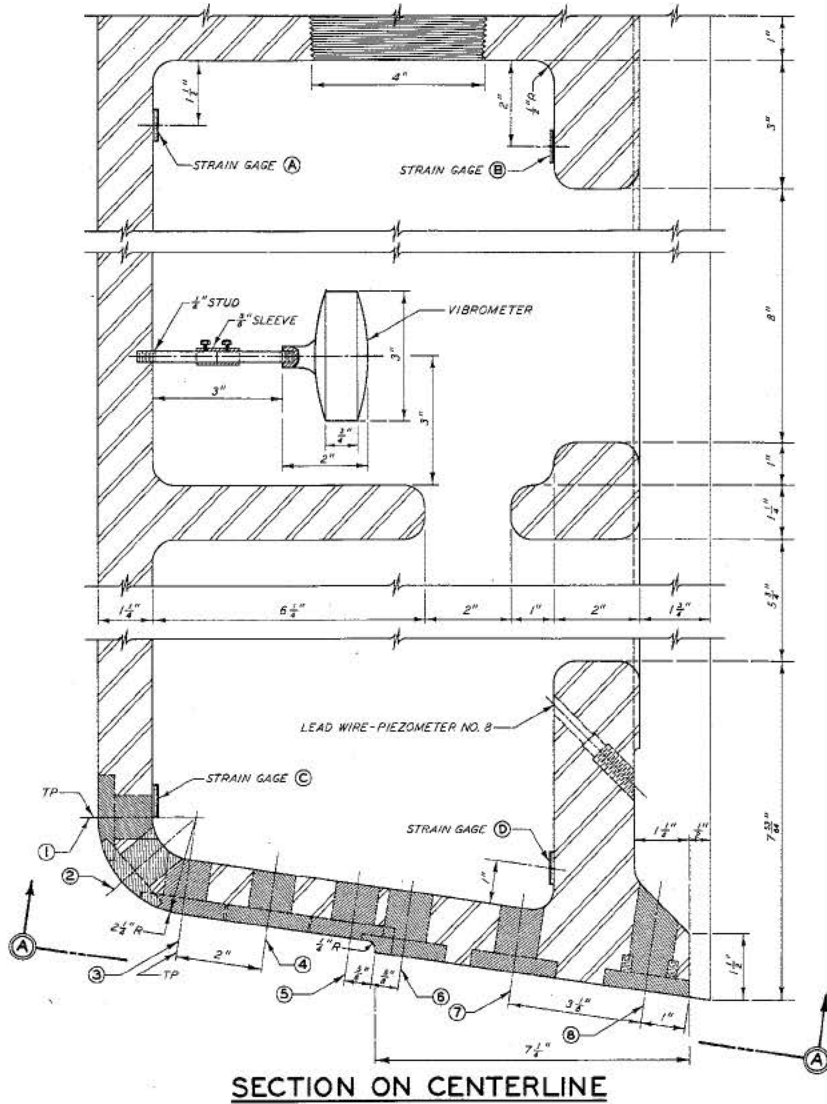
SECTION A-A



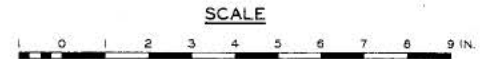
SECTION B-B

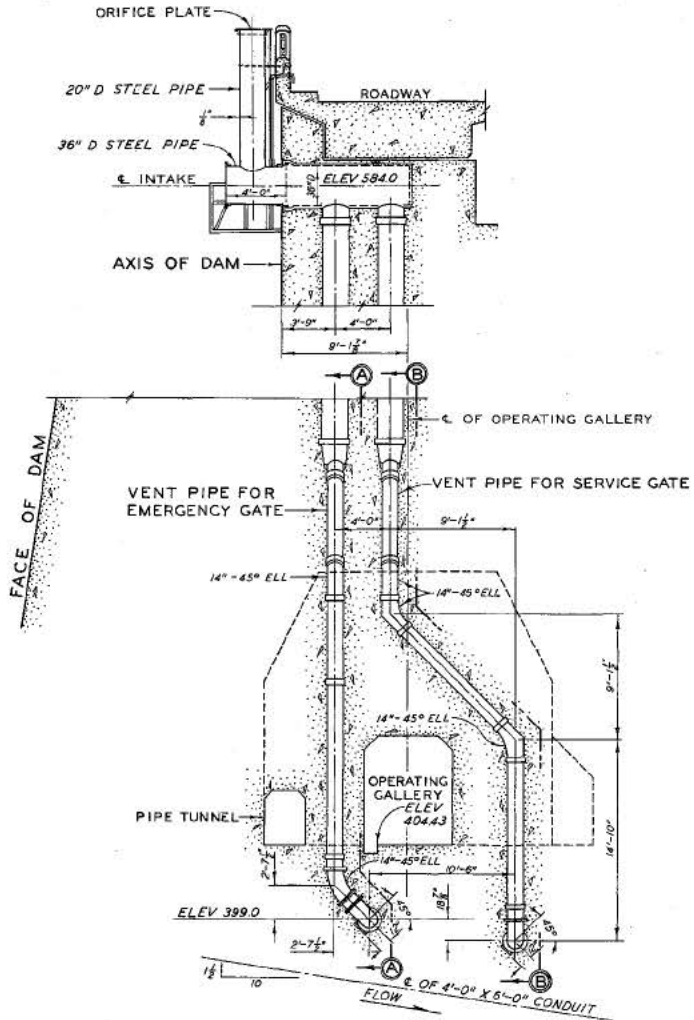


PIEZOMETER LOCATIONS
TYPE B GATE

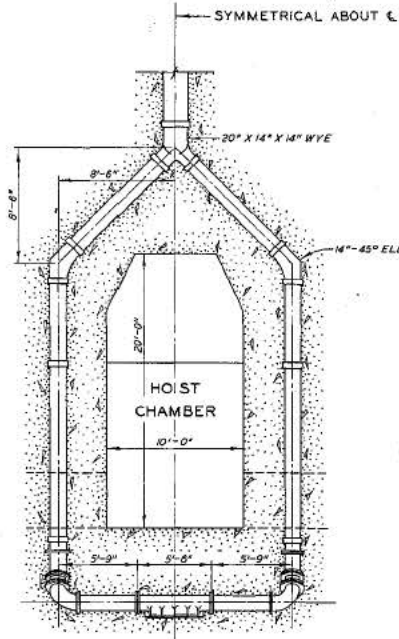


PRESSURE CELL, STRAIN GAGE
AND VIBROMETER LOCATIONS
TYPE A GATE

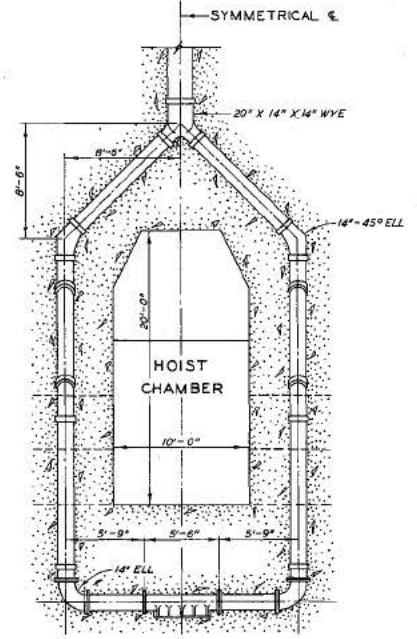




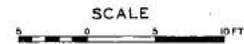
SECTIONAL ELEVATION



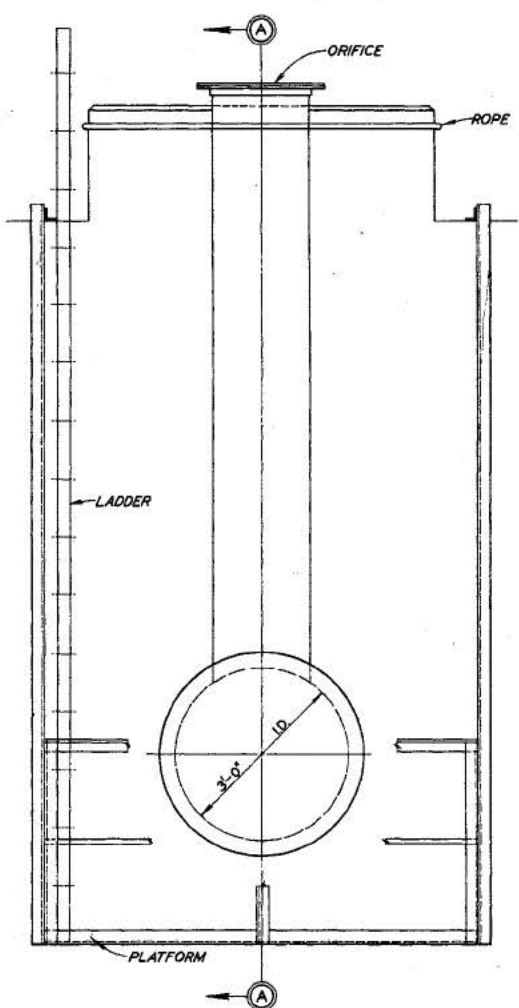
SECTION A-A



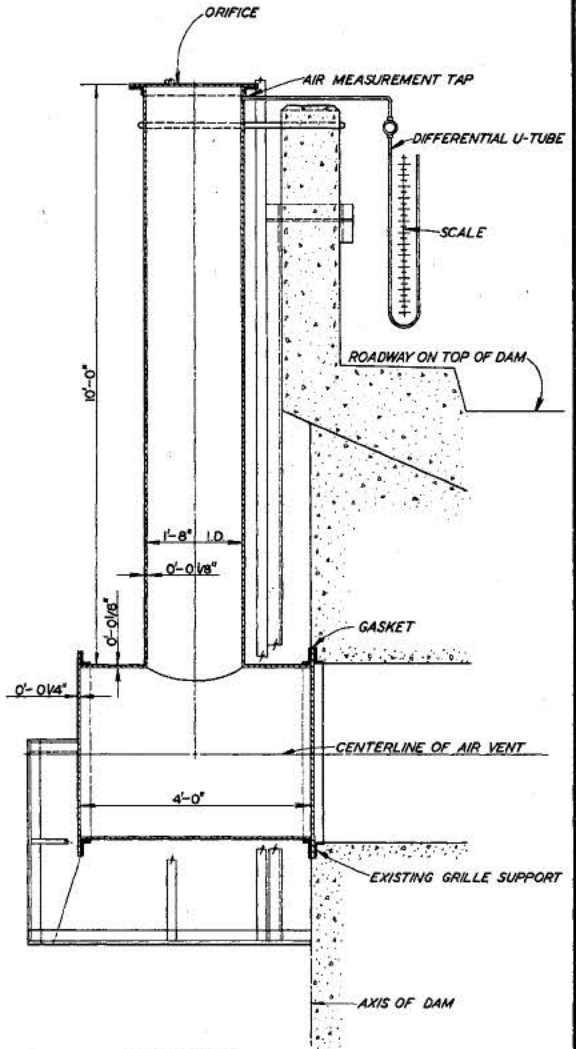
SECTION B-B



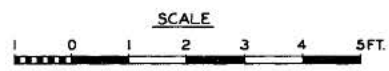
DETAILS OF AIR VENT



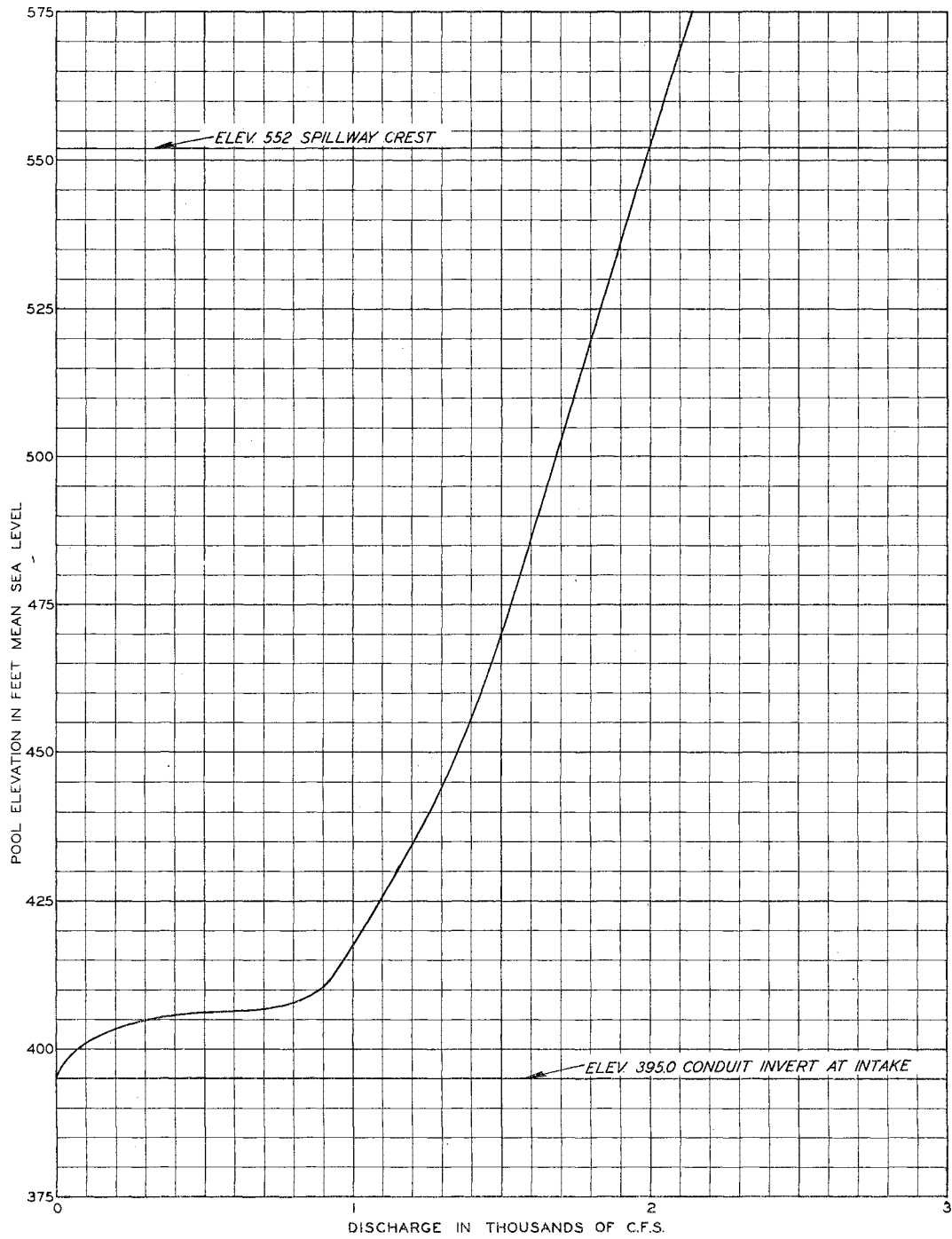
UPSTREAM ELEVATION



SECTION A-A

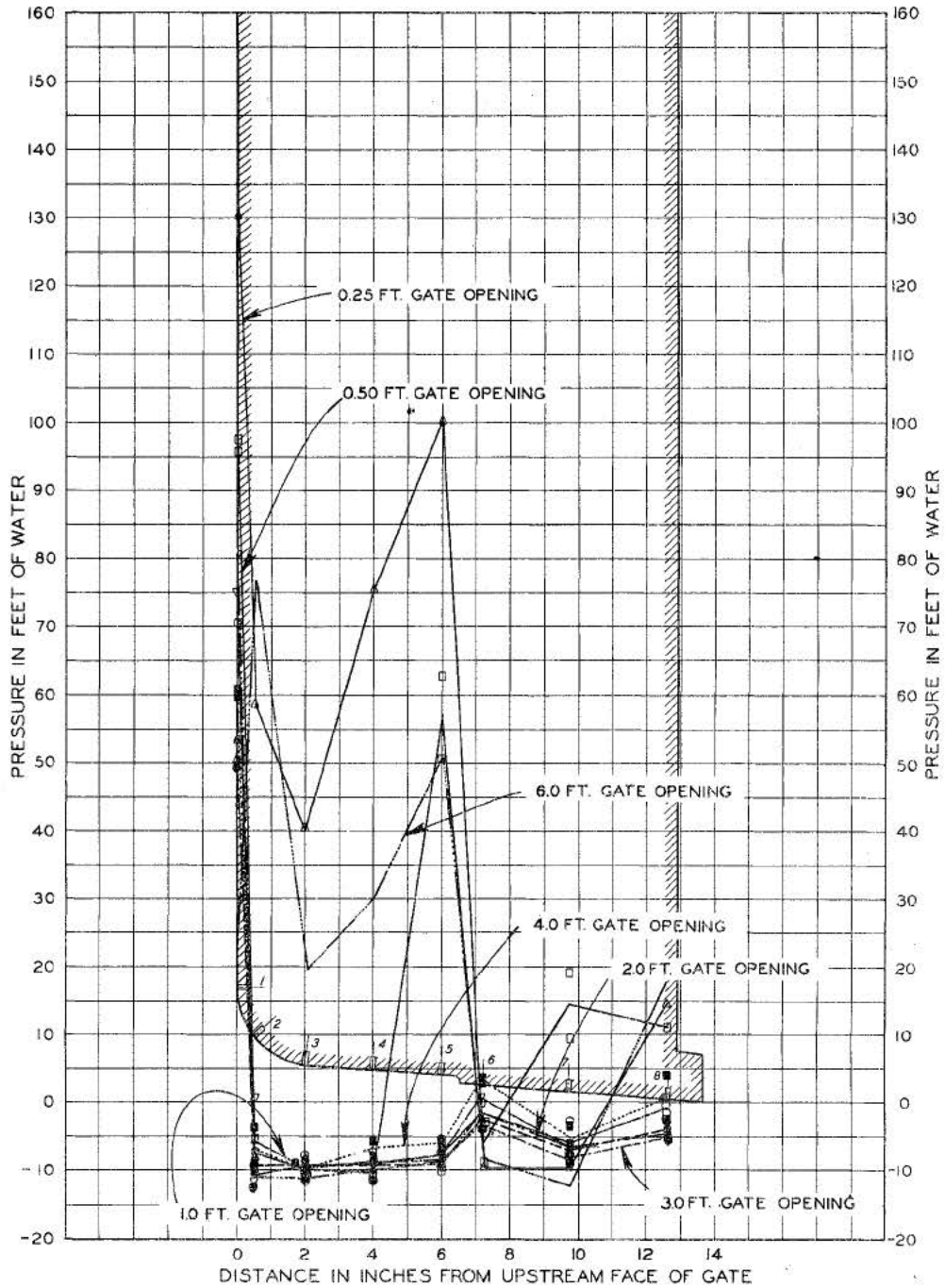


DETAILS OF AIR VENT EXTENSION



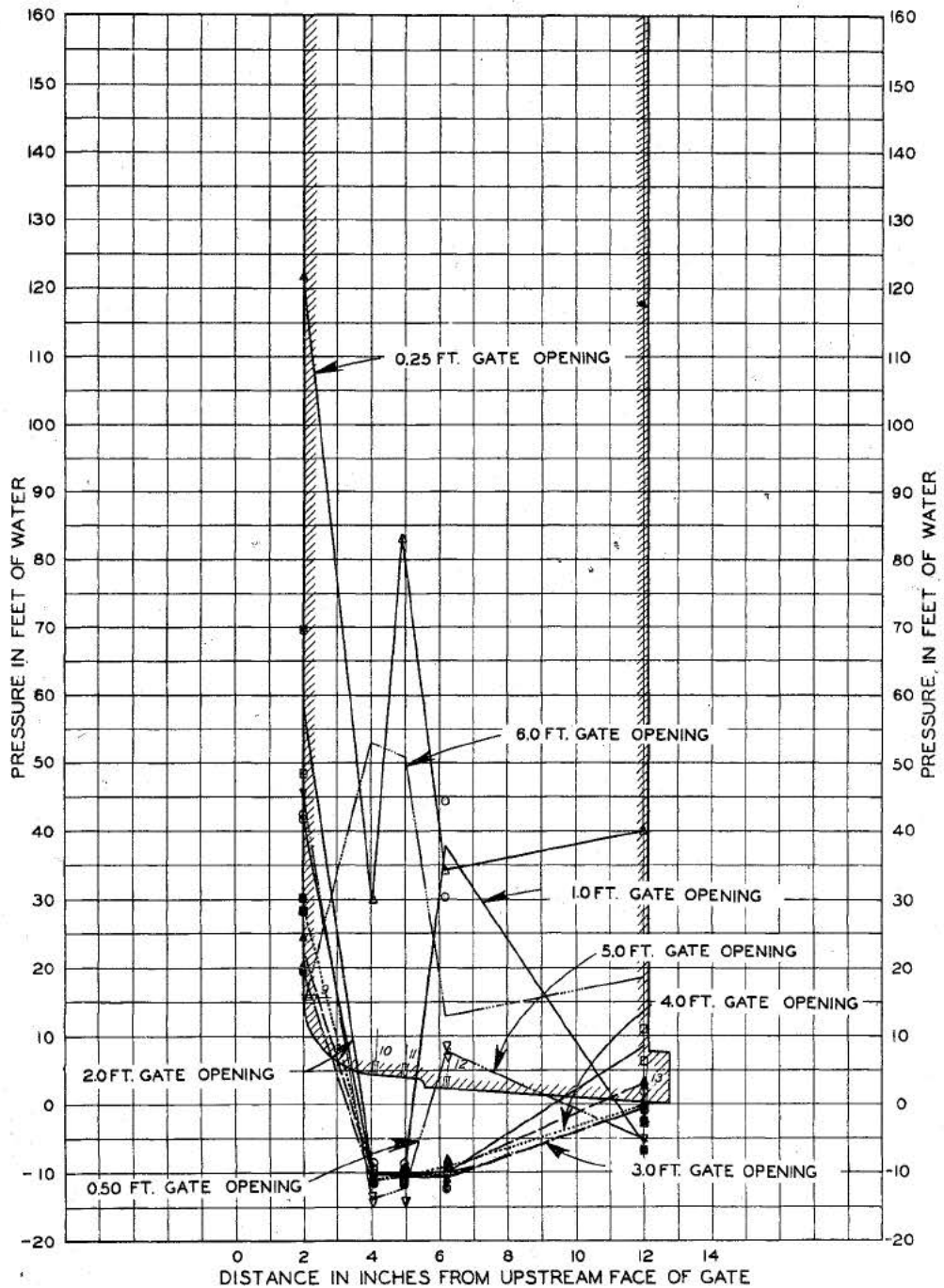
NOTE: DISCHARGE CURVE AS SHOWN
 COMPUTED FOR ONE 4 X 6 FT. CONDUIT.

DISCHARGE CURVE
GATE FULL OPEN



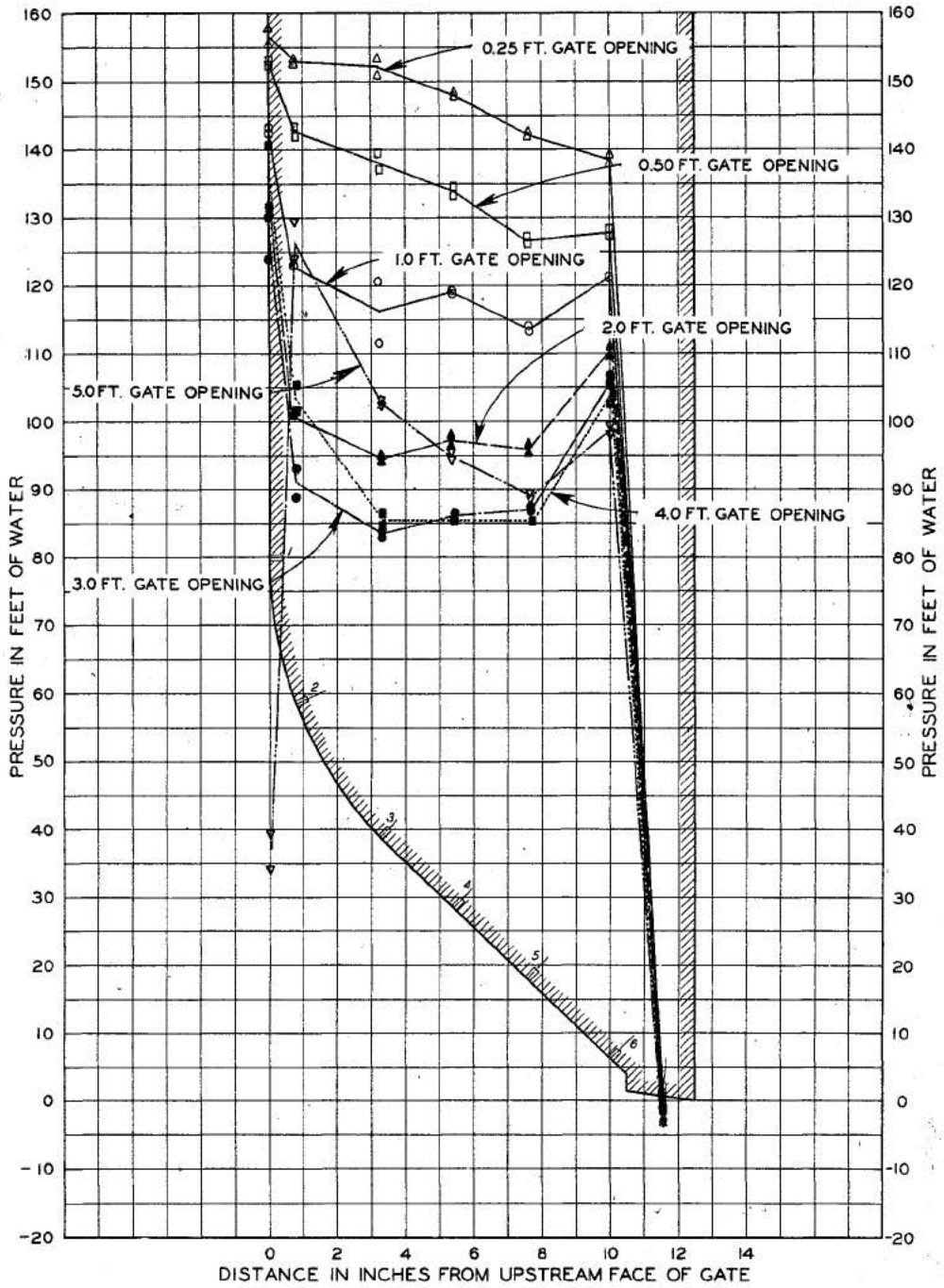
NOTE: OUTLINE OF GATE SHOWN FOR REFERENCE PURPOSES ONLY.
 PIEZOMETER ZEROES SHOWN ON TABLE I.
 AIR VENT OPEN FULL.

**PRESSURES ON CENTERLINE OF GATE LIP
 TYPE A GATE**



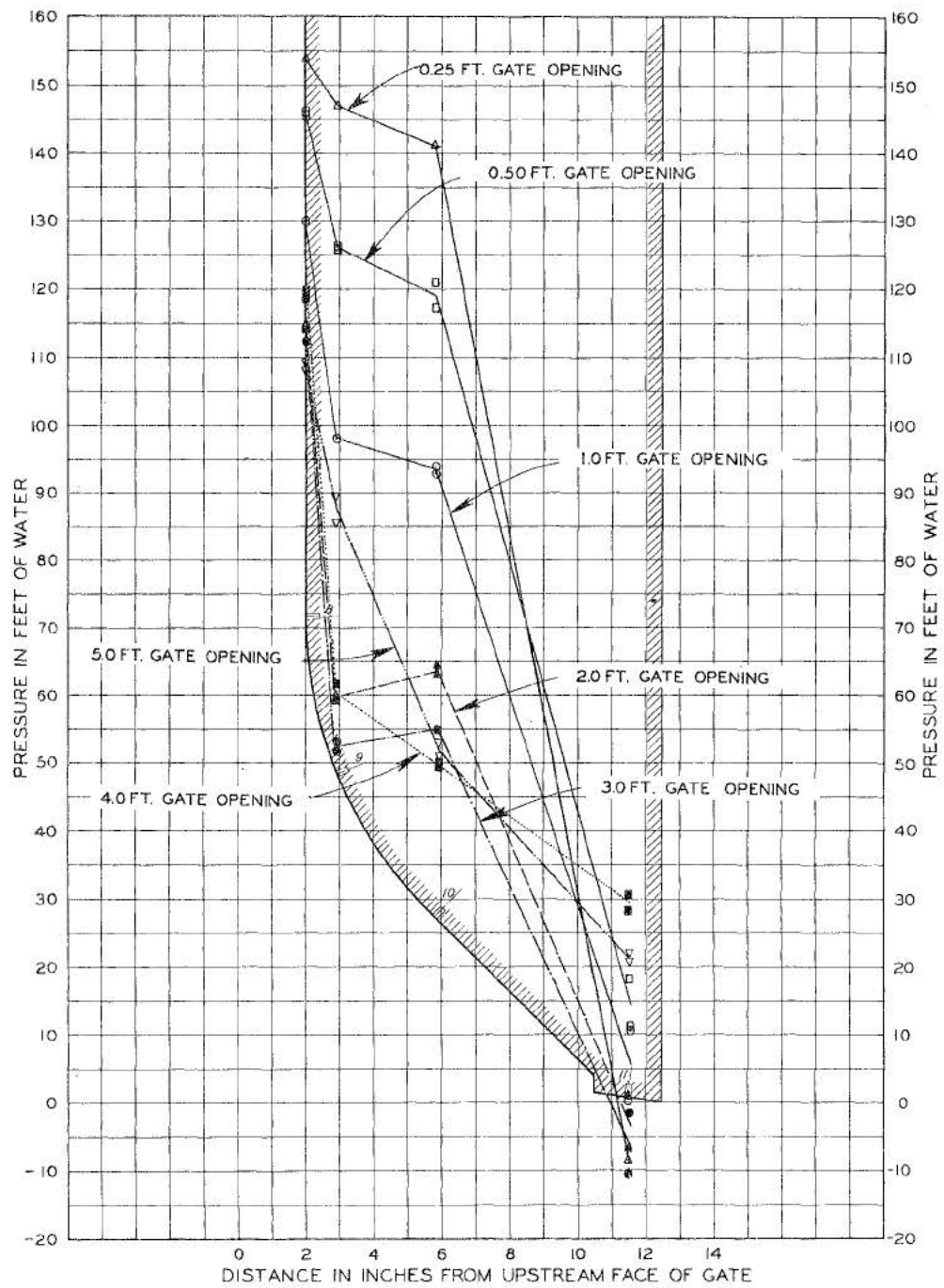
NOTE: OUTLINE OF GATE SHOWN FOR REFERENCE PURPOSES ONLY.
 PIEZOMETER ZEROES SHOWN ON TABLE I.
 AIR VENT OPEN FULL.

**PRESSURES ON SIDE OF GATE LIP
 TYPE A GATE**



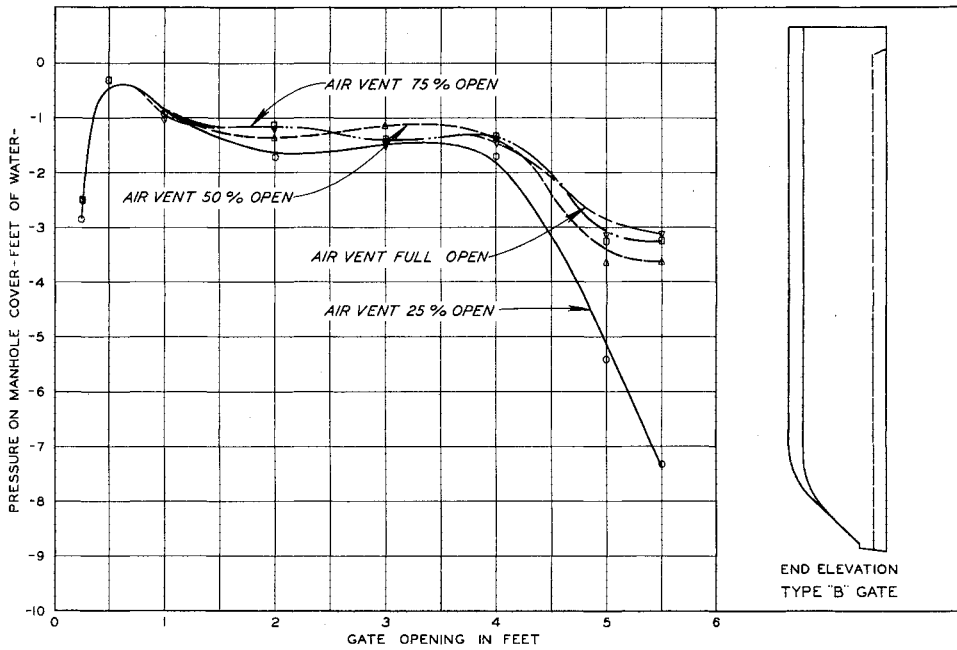
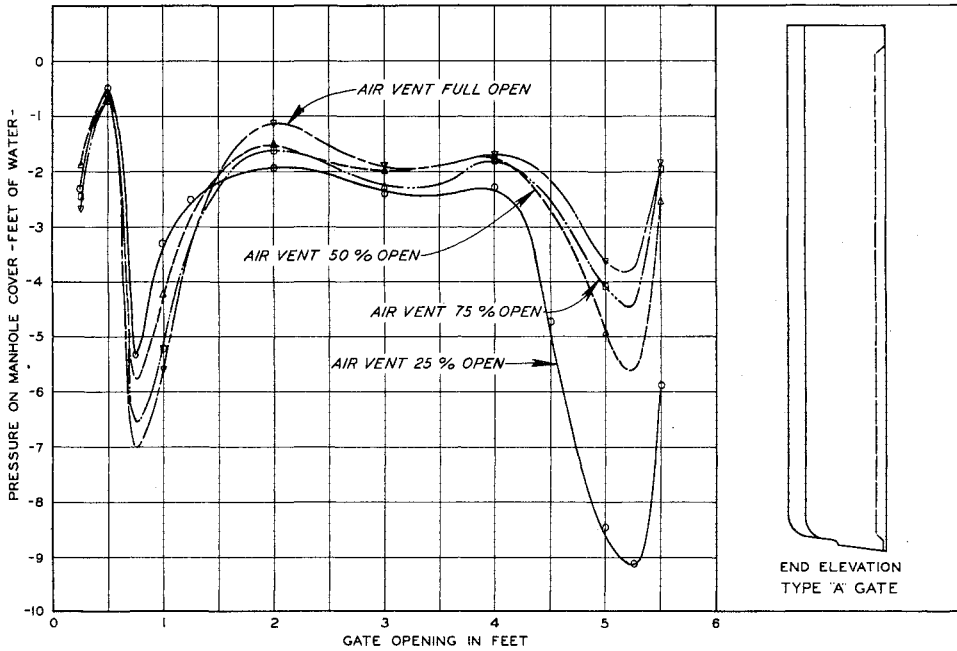
NOTE: OUTLINE OF GATE SHOWN FOR REFERENCE PURPOSES ONLY.
 PIEZOMETER ZEROES SHOWN ON TABLE 6.
 AIR VENT OPEN FULL.

**PRESSURES ON CENTERLINE OF GATE LIP
 TYPE B GATE**



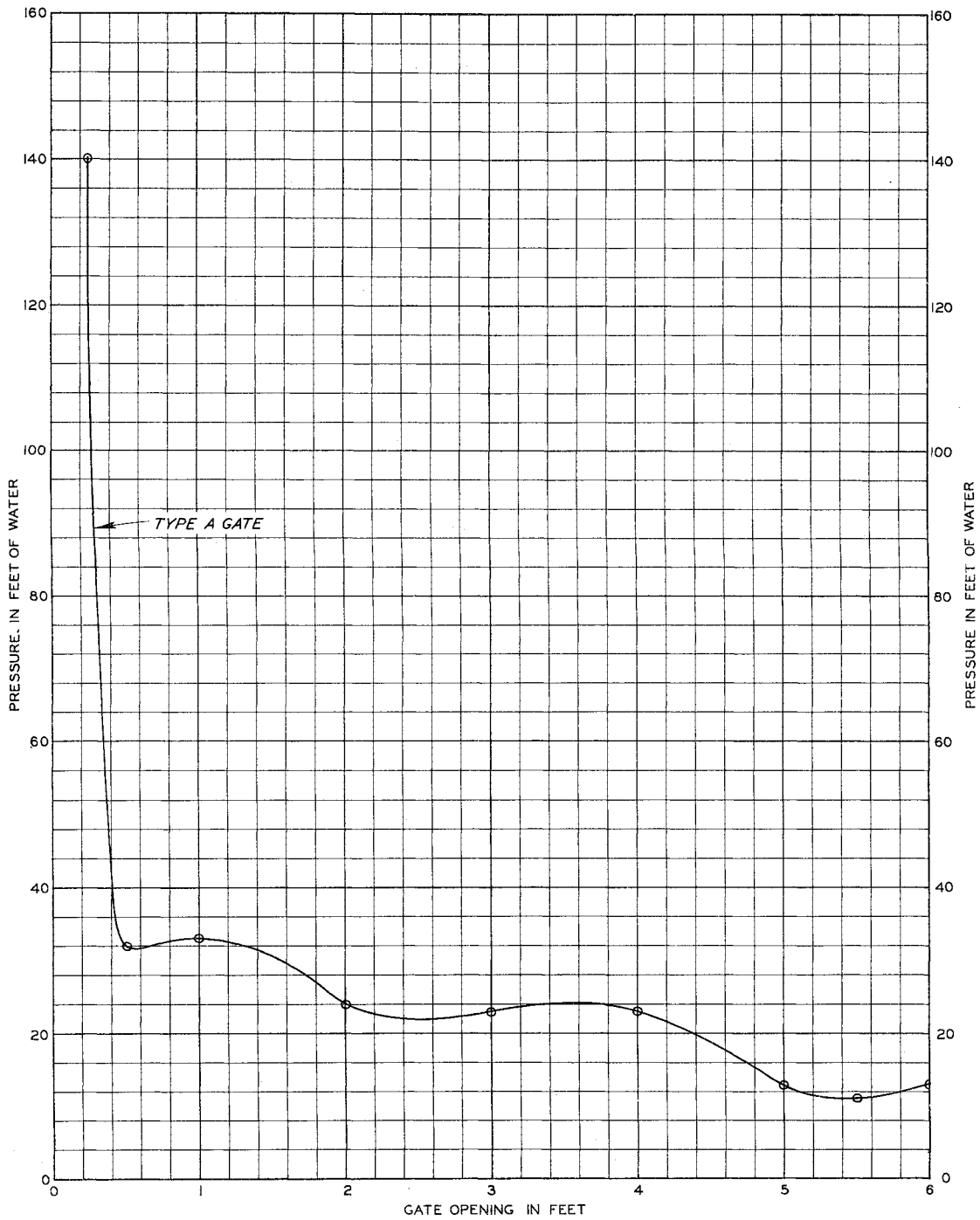
NOTE: OUTLINE OF GATE SHOWN FOR REFERENCE PURPOSES ONLY.
 PIEZOMETER ZEROES SHOWN ON TABLE 6.
 AIR VENT OPEN FULL.

PRESSURES ON SIDE OF GATE LIP
 TYPE B GATE



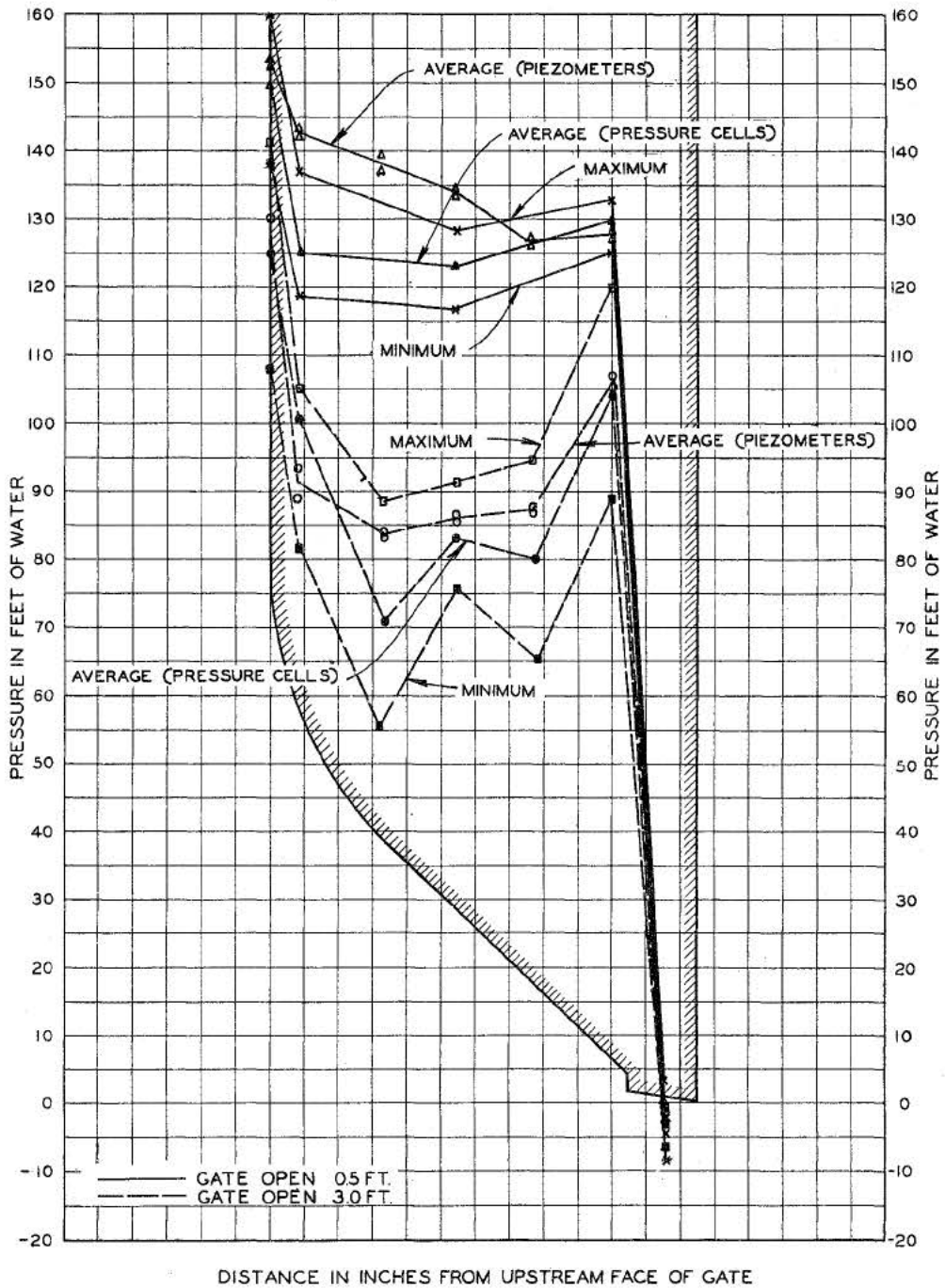
NOTE: LOCATION OF PIEZOMETER WHERE MANHOLE PRESSURES WERE MEASURED SHOWN ON PLATE 2.

EFFECT OF AIR VENT OPENING ON PRESSURES IN CONDUIT



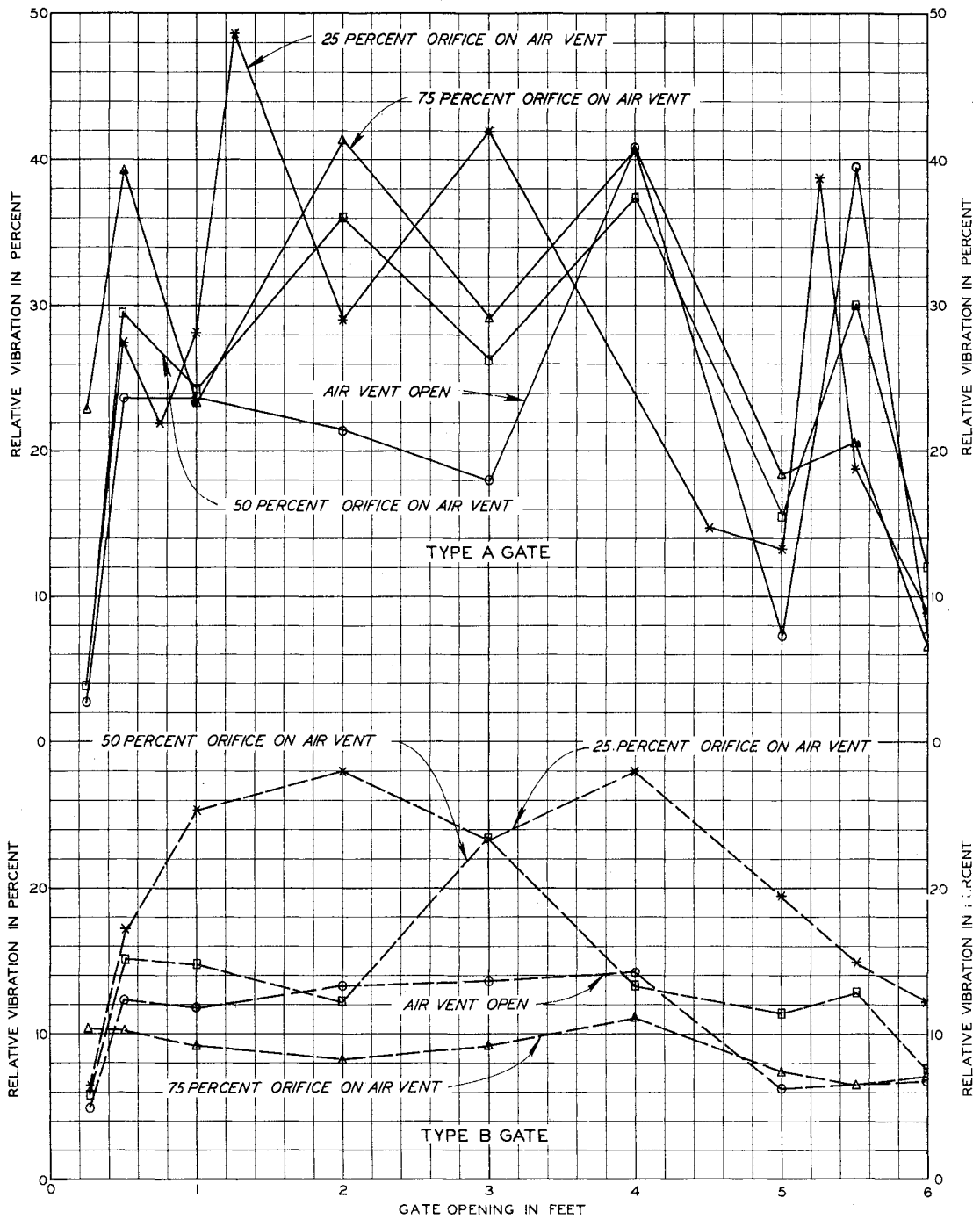
NOTE: AIR VENT UNRESTRICTED.
 BONNET PRESSURES WITH TYPE B GATE
 TO BE ADDED AS SOON AS PROCURED.

BONNET PRESSURES
 TYPES A AND B GATES



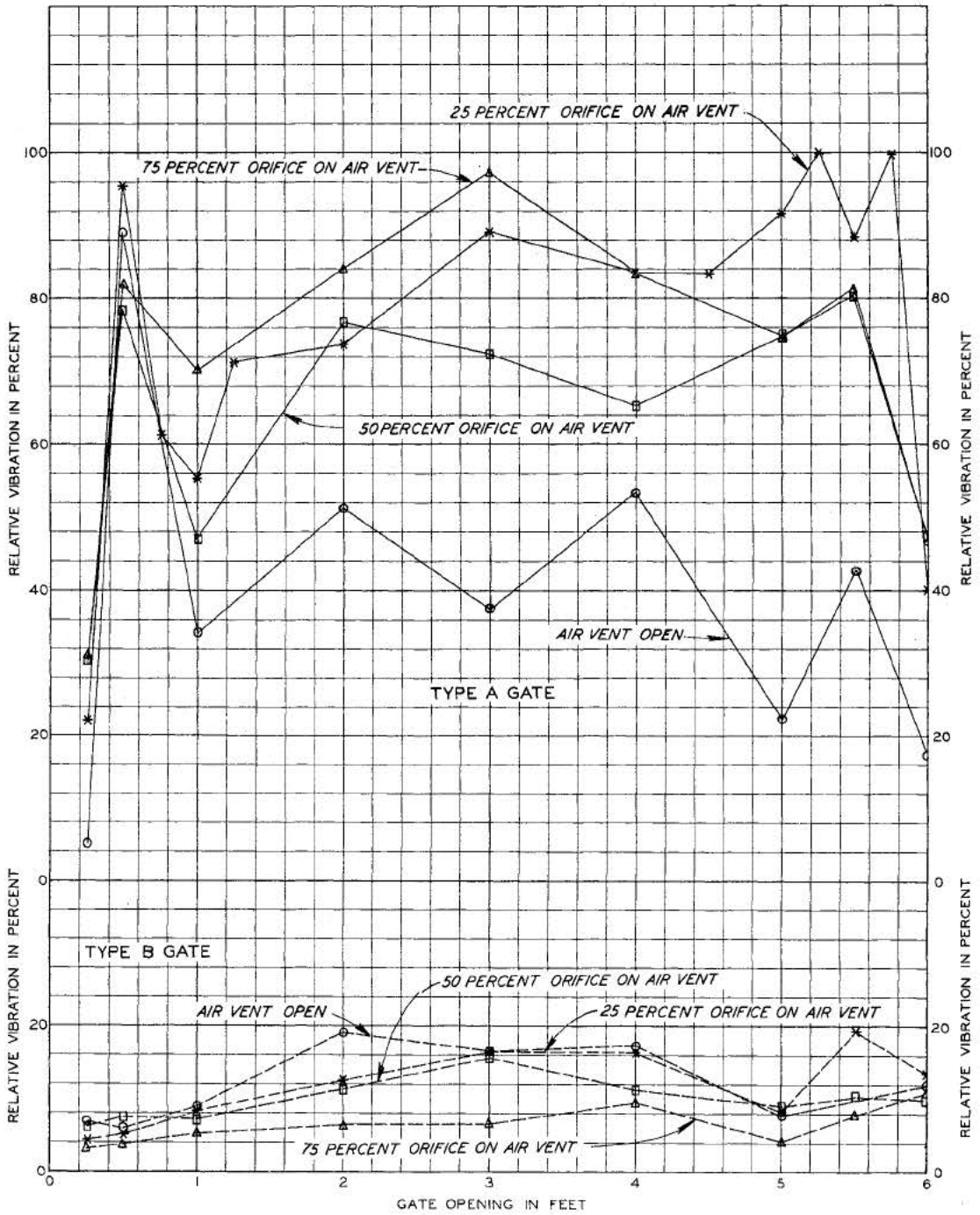
NOTE: OUTLINE OF GATE SHOWN FOR REFERENCE
 PURPOSES ONLY
 AIR VENT OPEN FULL

**PRESSURE FLUCTUATIONS
 ON CENTERLINE OF GATE LIP
 TYPE B GATE**



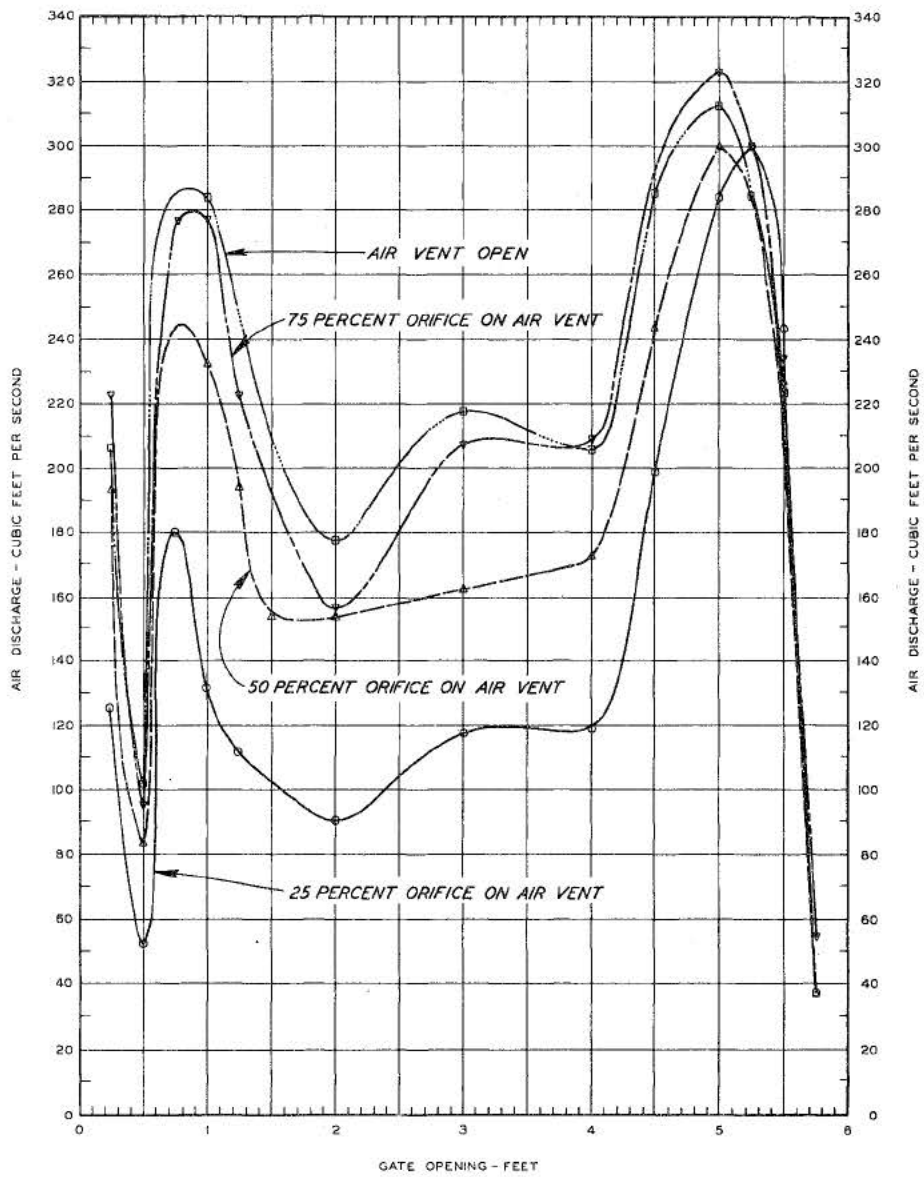
NOTE: RELATIVE VIBRATION IS IN PERCENT OF MAXIMUM VIBRATION IN HORIZONTAL PLANE FOR TYPE A GATE.

VIBRATION AMPLITUDE
VERTICAL PLANE
TYPE A AND B GATES



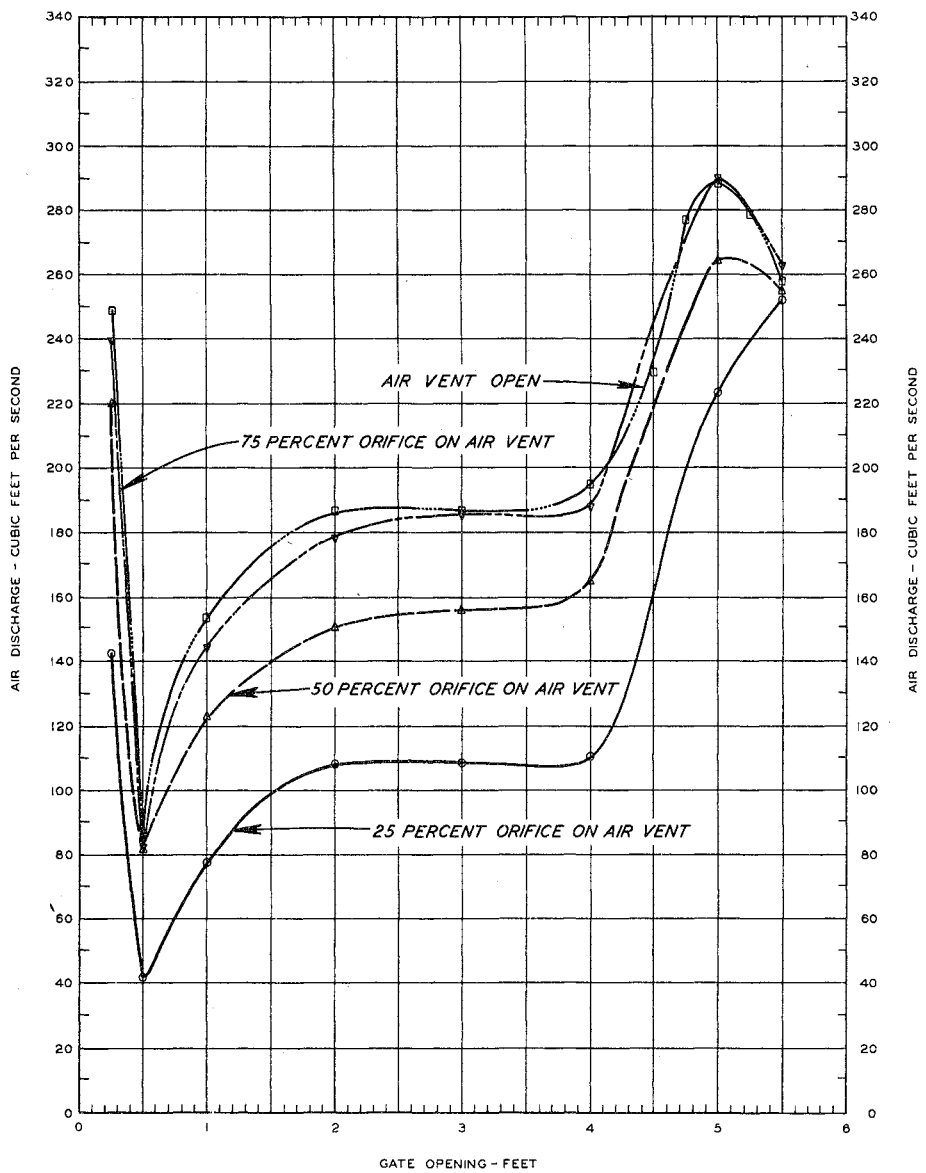
NOTE: RELATIVE VIBRATION IS IN PERCENT OF MAXIMUM VIBRATION IN HORIZONTAL PLANE FOR TYPE A GATE.

VIBRATION AMPLITUDE
HORIZONTAL PLANE
TYPE A AND B GATES



NOTE: ORIGINAL VENT 20 INCHES IN DIAMETER.

AIR DEMAND
TYPE A GATE



NOTE: ORIGINAL VENT 20 INCHES IN DIAMETER.

**AIR DEMAND
TYPE B GATE**