TECHNICAL REPORT H-68-4

EFFECT OF VALVE POSITION IN A SIDEWALL PORT FILLING SYSTEM NEWBURGH LOCK, OHIO RIVER

Hydraulic Model Investigation

by

J. O. Farrell
J. H. Ables, Jr.

September 1968

Sponsored by

U. S. Army Engineer Districts
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ARMY-MRC VICKSBURG, MISS.

FOREWORD

The model investigation reported herein was authorized by the Office, Chief of Engineers, U. S. Army, in the second indorsement, dated 6 June 1966, to a letter from the District Engineer, U. S. Army Engineer District, Louisville, dated 23 May 1966, and was sponsored jointly by the Louisville, Pittsburgh, Huntington, and Nashville Districts. The investigation was accomplished in the Hydraulics Division of the Waterways Experiment Station during the period August 1966 to February 1967 by Messrs. J. H. Ables, Jr., N. R. Oswalt, and J. O. Farrell under the general supervision of Mr. T. E. Murphy, Chief of the Structures Branch, and Mr. E. P. Fortson, Jr., Chief of the Hydraulics Division. This report was prepared by Messrs. Ables and Farrell and was reviewed by Mr. Murphy.

Directors of the Waterways Experiment Station during the conduct of the study and the preparation and publication of this report were COL John R. Oswalt, Jr., CE, and COL Levi A. Brown, CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
feet per second	0.3048	meters per second
tons	907.185	kilograms

SUMMARY

This report presents results of tests to investigate the effect of the relative position of the filling valves and port manifold on lock filling characteristics in a sidewall port system for a 110- by 1200-ft lock. These tests are supplemental to generalized tests on a lock of this size (Cannelton Main Lock, Ohio River).

Pressure and flow distribution data revealed that the most upstream port in the manifold must be at least 6.5 times the culvert height downstream from the filling valve in order to have this port out of the low pressure zone created by the valve. However, with as many as four ports in the low pressure zone no differences in filling time or hawser stresses could be detected from those obtained with the entire manifold downstream from the low pressure zone.

EFFECT OF VALVE POSITION IN A SIDEWALL PORT FILLING SYSTEM
NEWBURGH LOCK, OHIO RIVER

Hydraulic Model Investigation

PART I: INTRODUCTION

The Problem

1. Comprehensive model tests* of sidewall port filling and emptying systems for 110- by 1200-ft** locks, sponsored by U. S. Army Engineer Districts, Huntington, Pittsburgh, Louisville, and Nashville, resulted in design recommendations concerning port-to-culvert area ratio, port size and spacing, manifold position in the lock chamber, and deflectors at the upstream ports. Also, results from generalized model tests of 110- by 670-ft low-lift locks for the Arkansas River† supported these design recommendations. However, neither test series provided data on the influence of the position of the filling valves with respect to the port manifold.

2. Structural requirements at Newburgh Lock made it economically preferable that the filling valves be only about 63 ft from the port manifolds, while as a rule of thumb it was deemed that hydraulic considerations made it desirable that the distance between the valves and port manifolds be at least 80 ft. It was realized that location of the upstream ports in the low pressure zones downstream from the filling valves would result in a deficiency of flow through these ports during the valve opening period. However, information was not available on the extent of the low pressure zone below each valve or on the effects on overall filling

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* J. H. Ables, Jr., and M. B. Boyd, "Filling and Emptying System, Cannelton Main Lock, Ohio River, and Generalized Tests of Sidewall Port Systems for 110- by 1200-ft Locks," Technical Report No. 2-713, Feb 1966, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

** A table of factors for converting British units of measurement to metric units is presented on page vii.

† J. H. Ables, Jr., and M. B. Boyd, "Filling and Emptying Systems, Low-Lift Locks, Arkansas River Project," Technical Report No. 2-743, Nov 1966, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

characteristics of flow deficiency in the upstream ports during the valve opening period.

The Model

3. The basic model and model appurtenances and instrumentation used for the Cannelton Lock tests were used for this series of tests. Descriptions of these elements are contained in TR No. 2-713.* However, to make the data applicable to Newburgh Lock the filling and emptying valves and the culverts between these valves were made 14 ft wide by 16 ft high. Also, the port manifold in each culvert consisted of 24 type G ports (plate 1) with type 12 deflectors in front of the eight upstream ports in each culvert. The 24 type G ports resulted in a port-to-culvert area ratio of 0.91 and the port manifold was essentially centered in the lock chamber and extended over about 52 percent of the lock chamber. The position of the port manifold with respect to the filling valves and the miter gate for proposed Newburgh conditions is shown in plate 2. Also shown in plate 2 are the positions of the port manifold with respect to the filling valves for all conditions tested; each time the port manifold was shifted, the miter gates were shifted so that the position of the port manifold with respect to the miter gates was maintained the same as proposed for Newburgh Lock.

4. For all tests the filling valves were operated according to the schedule shown in plate 3. Data were collected for lifts of 15, 20, 30, and 40 ft.

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* Op. cit., page 1.

Pressures Downstream from Filling Valves

5. The initial series of tests involved the measurement of pressures on the roof of the culvert immediately downstream from a filling valve. For these tests the 24-port manifold was placed as far from the filling valve as was feasible; thus the most upstream port was at sta 3+92, 147 ft from the filling valve.

6. For each test condition preliminary runs were made to observe the time at which minimum pressure occurred. Then a test was made in which the manometers connected to the piezometers on the roof of the culvert were photographed at the time of minimum pressure. Plots of the pressure profile downstream from the valve at this time are shown in plates 4 and 5. Pertinent pressure data are summarized in the following tabulation.

		Occurrence of Minimum Pressure			Distance from Valve to Point Where Pressure Is Above Lock W.S. El, ft	Extent of Low Pressure Zone, ft
Lift ft	Valve Time min	Time min	Percent Gate Opening	Lock Chamber W.S. El*		
15	1	0.5	38	341.0	7	85
	2	1.4	61	342.0	55	105
	4	2.1	41	342.5	90	105
	8	3.7	29	343.0	85	105
20	1	0.6	50	341.5	51	105
	2	1.3	55	342.0	67	95
	4	2.2	44	343.0	85	105
	8	4.2	41	343.0	95	95
30	1	0.7	61	342.0	49	105
	2	1.4	61	342.5	65	100
	4	2.3	46	344.0	86	110
	8	4.0	38	345.0	100	110
40	1	0.7	61	342.0	64	105
	2	1.4	61	343.5	58	85
	4	2.7	58	345.0	90	105
	8	4.3	42	347.5	90	105

* At the beginning of each test the lock chamber water surface was at el 341.0. All elevations are in feet above mean sea level.

General conclusions drawn from these data follow:

- a. Occurrence of minimum pressure varied from a valve opening of about 60 percent at a 1-min valve time to about 40 percent at an 8-min valve time.
- b. Pressures did not drop below the lock chamber water surface, and thus reverse flow was unlikely at distances greater than about 90 ft (5.5 times the culvert height) downstream from the valve.
- c. The extent of the reduced pressure zone downstream from the valve was independent of lift and valve time and amounted to about 105 ft (6.5 times the culvert height).
- d. Minimum pressure for each lift occurred with a 4-min valve time (plate 6).

Flow Through Upstream Port of Manifold

7. Filling tests were made to determine the average velocity through the upstream port with the manifold at various positions with respect to the filling valve. The manifold was shifted to place the first port at sta 2+52, 2+80, 3+08, 3+36, and 3+64, which correspond to valve-to-port distances of 7, 35, 63, 91, and 119 ft, respectively. Each test was made with a 40-ft lift and a 2-min valve time.

8. Flow through the port was computed from velocity measurements taken at nine locations in the port opening at the face of the lock chamber wall. Sequence photographs of manometers connected to a three-pitot-tube rig were taken to record flow velocities at specific intervals during the filling operation. Because of lags in the manometer tubes this method no doubt resulted in indications of lesser velocities than actually occurred during periods of increasing velocities and higher velocities than actually occurred during periods of decreasing velocities. However, the pattern of flow with respect to time is considered adequate for the purposes of these tests. Average velocities developed from the measurements are plotted in plate 7 together with velocities computed from the filling curve and an assumed ideal manifold in which each port carries an equal share of the total flow entering the lock chamber.

9. These measurements substantiate the indication obtained from the pressure data that the first port must be about 6.5 times the culvert

height downstream from the valve before it will discharge at near the desired rate of flow during the valve opening period.

Hawser Stresses

10. Hawser stresses on a full tow were measured with the port manifold positioned so that the most upstream port was 7, 63, and 119 ft from the filling valve. Tests were made at lifts of 20 and 40 ft with 25- and 40-ft submergences. Pertinent hawser stress data are listed in table 1 and are plotted in plates 8 and 9. Filling times for lifts of 20 and 40 ft are plotted in plate 10.

11. For any set of hydraulic conditions and valve time, maximum hawser stresses were approximately the same for each of the three manifold positions tested. However, the upstream hawser stresses in this model were consistently greater than would be expected from consideration of data in TR 2-713. For Newburgh conditions of an 18-ft lift and 31-ft submergence, the lock was filled in about 8 min (4-min valve time), with maximum hawser stresses of about 5 tons; data in TR 2-713 indicate that this lock should be filled in about 7.5 min, with hawser stresses not exceeding 5 tons.

PART III: DISCUSSION

12. This series of tests revealed that the most upstream port in the manifold must be at least 6.5 times the culvert height downstream from the filling valve in order to have this port out of the low pressure zone downstream from the valve and thus permit it to discharge approximately its share of the total flow. However, with the port manifold placed in a position that resulted in the first two and the first four ports being within the low pressure zone downstream from the valve, no differences in filling time or hawser stresses could be detected from those obtained with the manifold placed so that all ports were outside of the low pressure zone.

13. The minimum pressure in the culvert downstream from the valve for each lift occurred with a 4-min valve time. Since the minimum pressure is influenced by the inertia of the water in the culvert and the head differential at the time the valve reaches the critical opening, the valve speed that results in minimum pressure probably is dependent upon the length of culvert and the port-to-culvert area ratio. In most 600-ft locks tested to date, minimum pressures have been observed with 2-min valve times.

14. The reason for the upstream hawser stresses in this model being consistently greater than would be expected from consideration of data in TR 2-713 is uncertain. It could be due to the difference in port and deflector geometry.

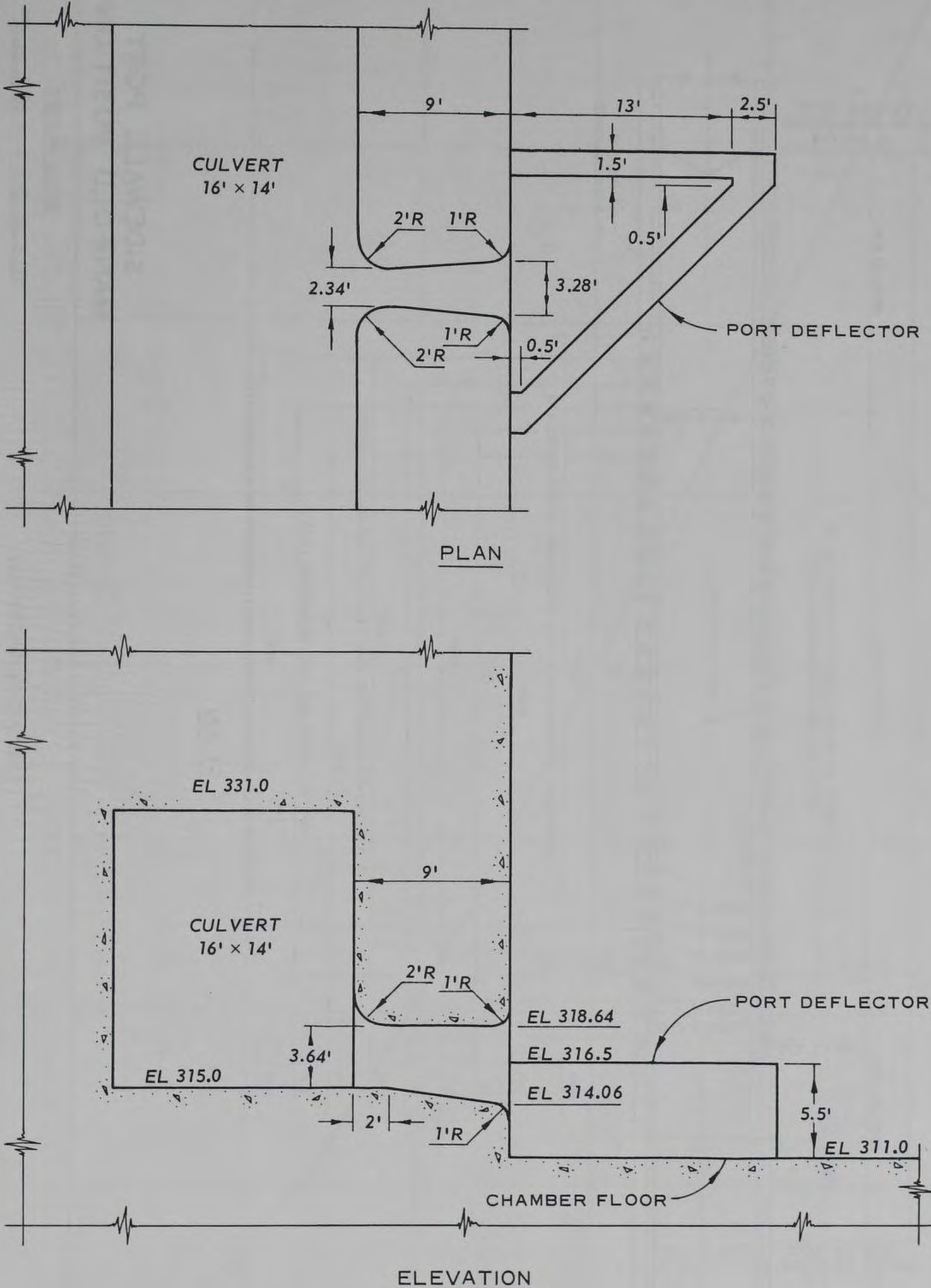
Table 1

Filling Characteristics with Distance Between Filling Valve and Most Upstream Port Varied

Port Manifold Centered Between Miter Gate Pintles

						Maximum Hawser Stresses											
						Longitudinal				Upstream Transverse				Downstream Transverse			
	Sub-				Fill-	Upstream		Downstream		Left		Right		Left		Right	
Lift ft	mergence ft	Lower Pool El	Upper Pool El	Valve Time min	Filling Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
					Upstream Port of Manifold 7 ft from Filling Valve												
20	25	336	356	2	7.6	11.9	1.6	5.3	0.7	3.5	3.4	5.5	2.9	5.9	2.4	5.5	1.8
				4	8.7	7.6	1.8	3.4	0.8	3.5	4.7	3.1	3.5	2.8	5.2	3.9	3.4
				8	10.9	3.6	3.2	1.3	1.9	1.2	5.5	2.4	6.0	2.0	9.3	3.1	7.8
40	25	336	376	2	10.5												
				4	11.6	12.3	1.8	4.4	0.8	4.3	5.6	4.7	2.9	3.1	5.2	9.4	2.8
				8	13.8	7.3	5.7	2.2	1.1	2.4	8.1	7.0	6.3	2.4	9.2	7.4	7.3
20	40	351	371	2	7.6	9.5	2.5	5.4	3.1	2.0	2.2	1.6	1.6	2.4	3.4	2.4	1.7
				4	8.7	3.9	1.6	2.0	4.7	1.2	4.6	2.0	3.7	1.2	5.4	2.4	3.6
				8	10.9												
40	40	351	391	2	10.5	17.0	2.4	5.1	0.5	3.9	2.9	4.7	2.8	3.9	3.0	6.6	2.9
				4	11.6	8.1	3.8	2.7	0.7	5.1	5.3	3.9	4.0	3.9	4.6	6.2	3.3
				8	13.8	4.8	7.2	1.6	0.9	3.0	7.8	4.4	7.2	1.9	7.9	4.5	5.5
					Upstream Port of Manifold 63 ft from Filling Valve												
20	25	336	356	2	7.6	10.8	2.3	6.4	0.8	3.9	3.0	3.1	3.1	2.9	3.5	4.9	1.9
				4	8.7	5.9	3.9	3.1	0.8	2.3	4.6	3.1	4.3	2.3	4.5	4.3	3.3
				8	10.9												
40	25	336	376	2	10.5	23.4	2.4	8.6	0.7	6.4	3.1	5.9	1.5	3.9	3.0	10.2	1.8
				4	11.6	12.5	3.5	4.3	0.8	4.5	4.7	7.0	3.7	6.6	4.3	4.3	3.6
				8	13.8												
20	40	351	371	2	7.6	9.3	2.4	4.1	3.1	2.5	2.9	2.5	3.5	2.3	3.7	2.7	3.5
				4	8.7	3.9	4.0	2.0	0.7	1.6	4.8	2.0	4.2	1.6	4.4	2.1	3.4
				8	10.9												
40	40	351	391	2	10.5	16.4	2.1	5.0	0.4	5.0	3.8	4.6	2.3	4.0	2.7	5.8	2.9
				4	11.6	8.2	4.0	2.5	5.5	3.1	4.7	3.3	4.2	2.5	6.8	6.6	3.4
				8	13.8												
					Upstream Port of Manifold 119 ft from Filling Valve												
20	25	336	356	2	7.6	12.0	2.1	6.1	0.7	3.9	2.1	2.8	3.3	3.1	3.1	4.3	2.9
				4	8.7	7.3	3.5	3.4	0.8	2.8	5.2	3.1	3.7	2.8	4.8	4.7	3.6
				8	10.9	3.5	5.9	1.6	0.9	1.2	4.1	2.8	6.7	2.0	7.6	2.8	7.0
40	25	336	376	2	10.5	25.7	2.1	7.8	0.7	4.3	2.1	3.9	5.0	5.1	2.1	10.2	2.2
				4	11.6	13.3	3.6	4.3	0.7	3.5	5.0	4.3	4.0	4.3	4.5	7.4	3.0
				8	13.8	7.4	5.9	2.0	1.1	4.3	8.4	5.5	5.5	3.9	8.8	8.4	6.9
20	40	351	371	2	7.6	7.6	2.3	3.5	0.7	1.6	3.0	2.8	2.2	3.1	3.1	3.1	2.5
				4	8.7	3.9	3.6	2.2	0.6	1.6	4.7	2.0	3.8	1.6	5.3	2.8	3.4
				8	10.9	1.4	4.8	1.0	9.2	1.6	9.7	2.0	5.7	1.6	8.8	2.4	5.7
40	40	351	391	2	10.5	16.1	2.2	5.9	2.8	2.9	2.9	3.5	2.1	3.1	3.3	5.1	3.1
				4	11.6	8.0	3.6	2.6	0.6	3.1	4.7	3.1	3.1	3.1	7.4	5.5	3.0
				8	13.8	4.9	8.1	1.5	0.8	2.0	7.1	3.1	7.0	2.8	8.4	5.1	6.9

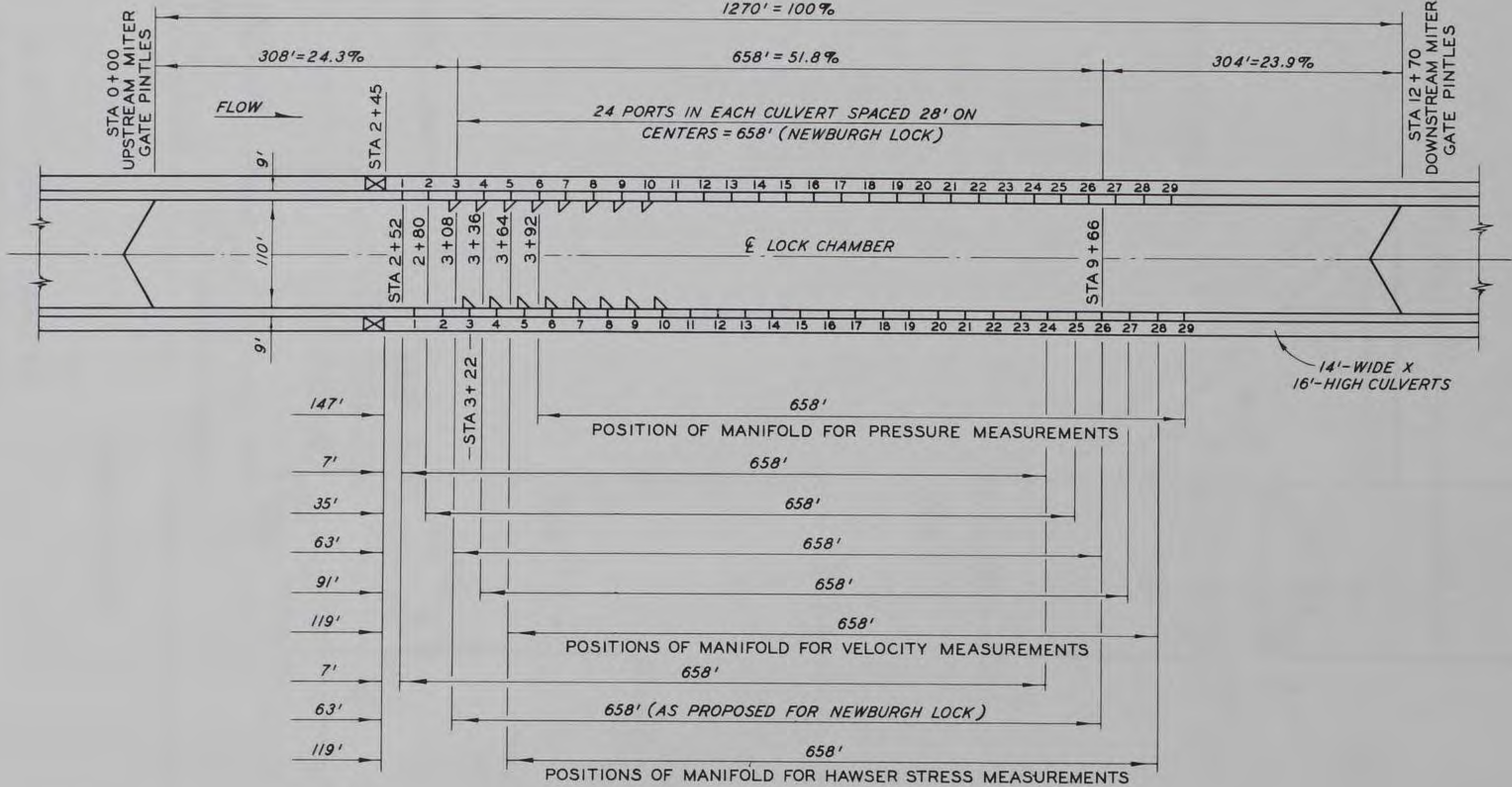
Note: Time listed under hawser stresses is time of occurrence after beginning of movement of culvert valve. 18-barge tow (33,900 tons displacement) positioned 50 ft below upstream miter gate pintles. 24 ports spaced 28 ft on centers, port-to-culvert area ratio 0.91.



SIDEWALL PORT TYPE G
PORT DEFLECTOR TYPE 12

SCALE IN FEET

5 0 5 10

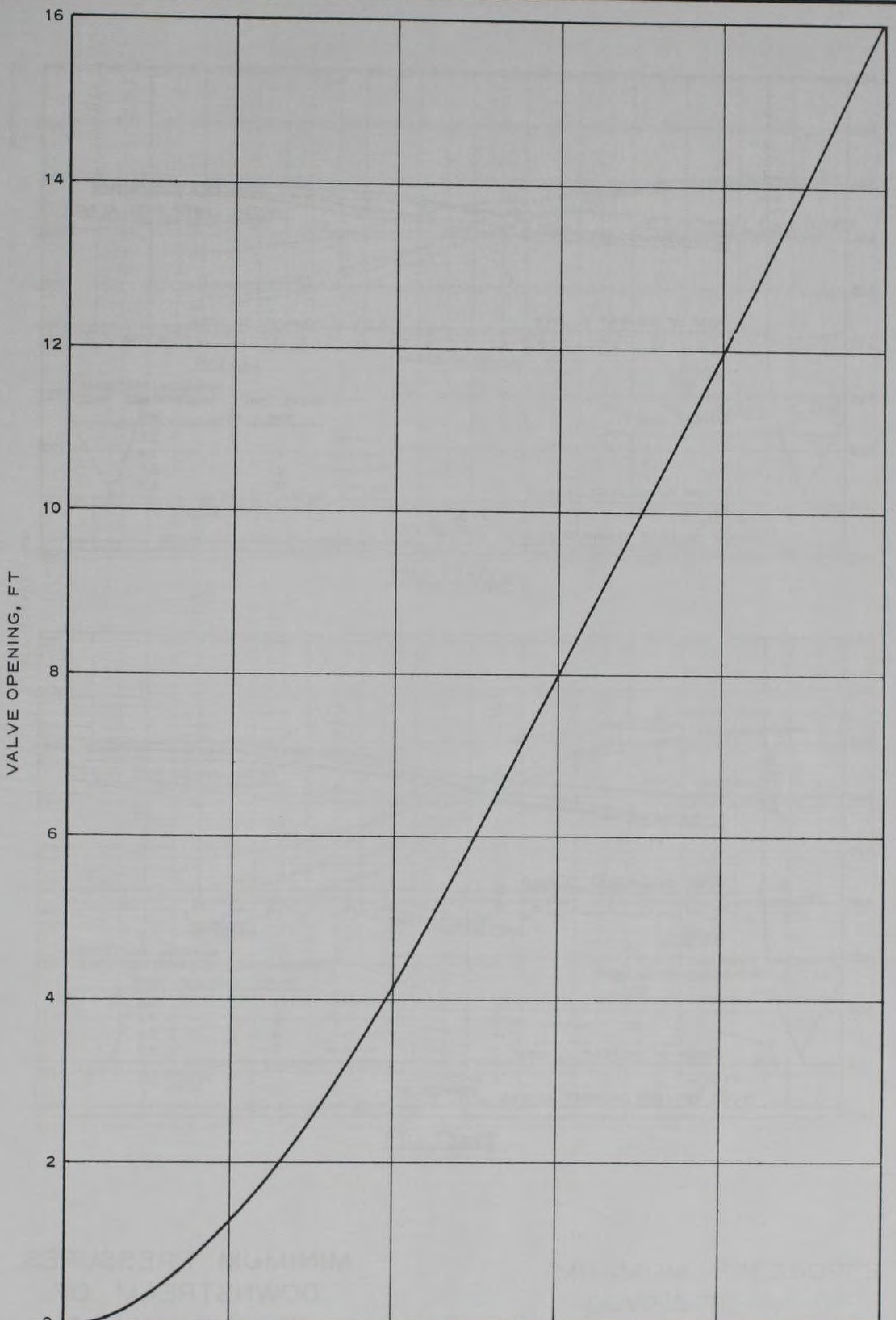


PLAN

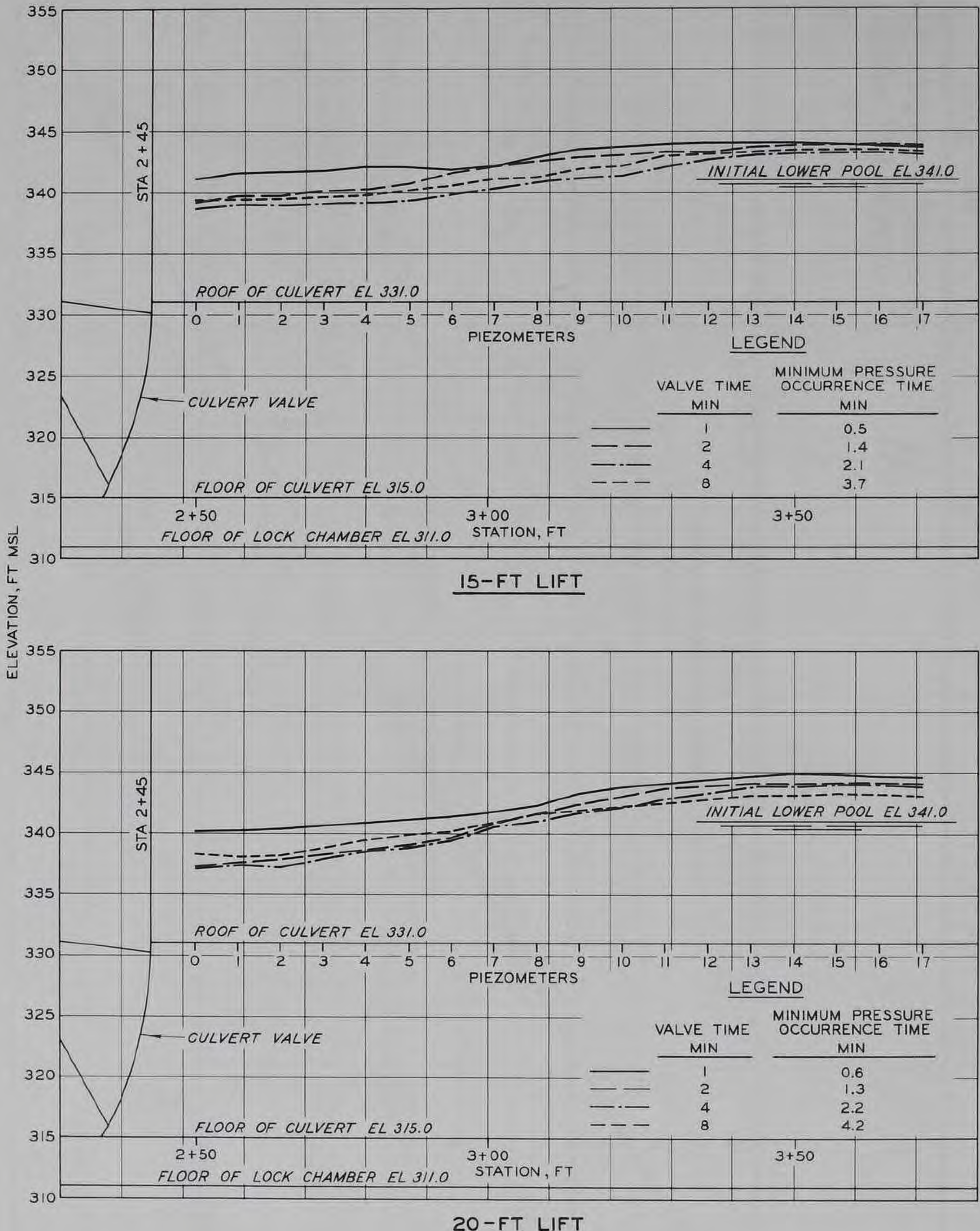
SIDEWALL PORT MANIFOLD POSITIONS

SCALE IN FEET

100 0 100 200

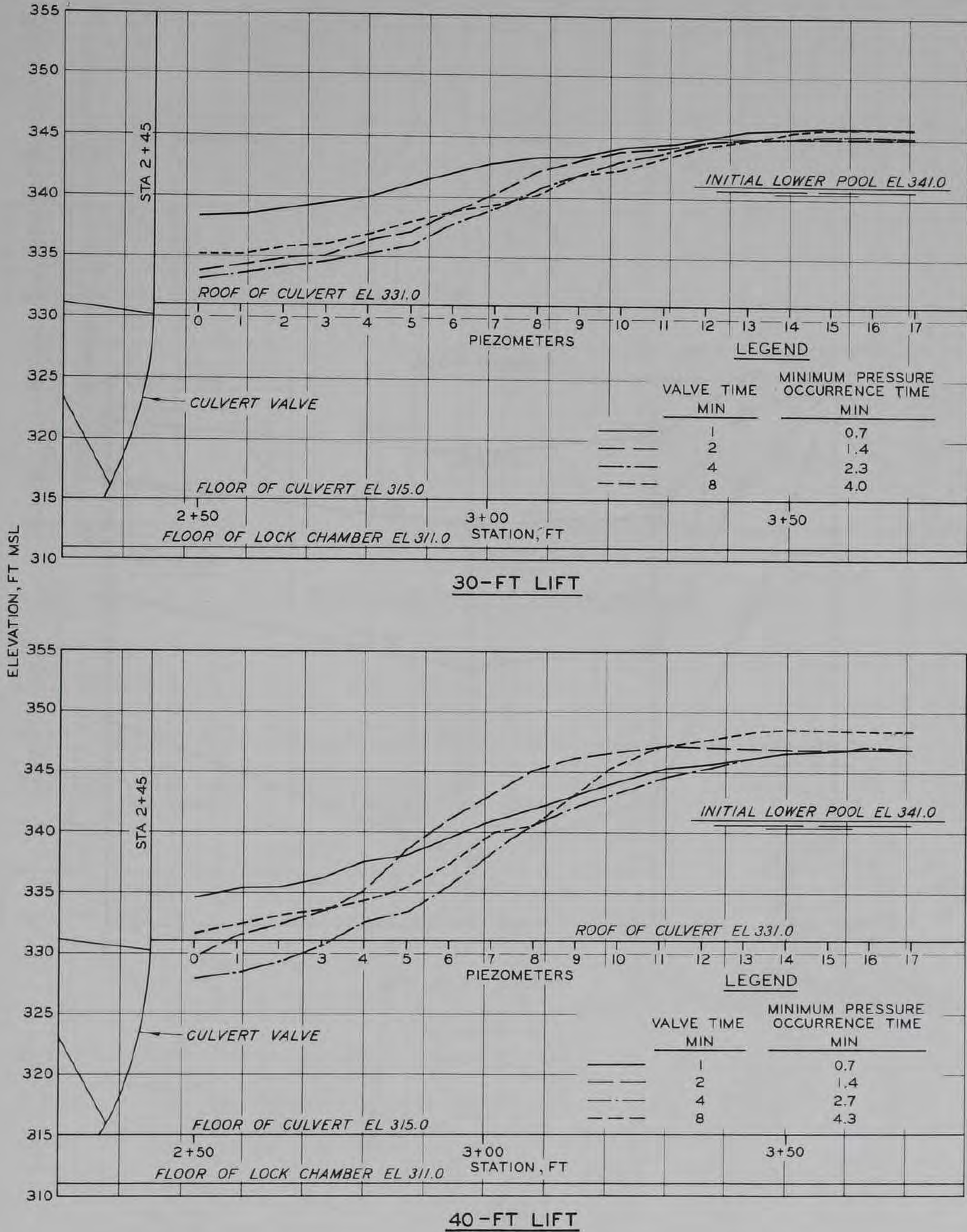


VALVE SCHEDULE



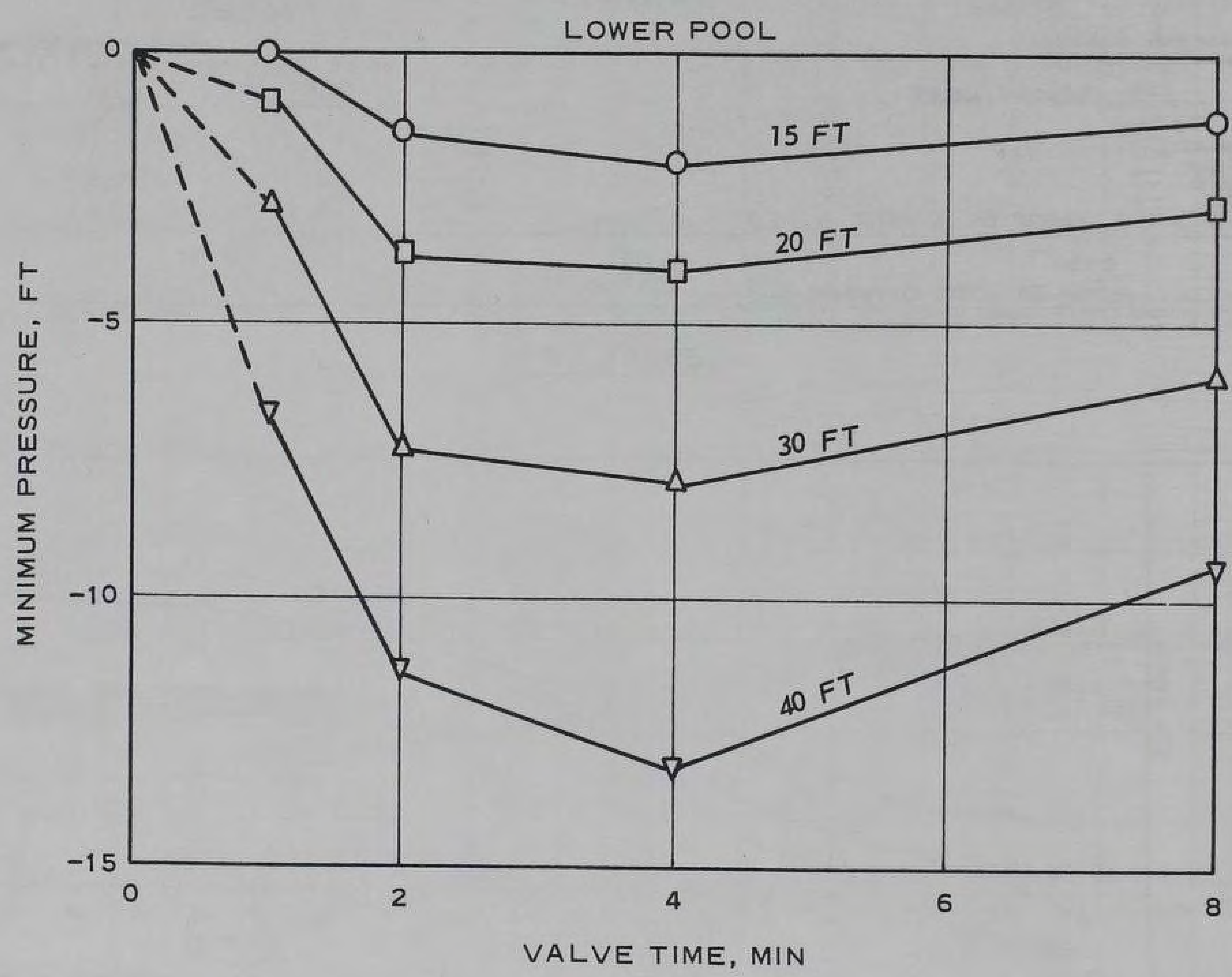
MINIMUM PRESSURES DOWNSTREAM OF FILLING VALVES

15- AND 20-FT LIFTS

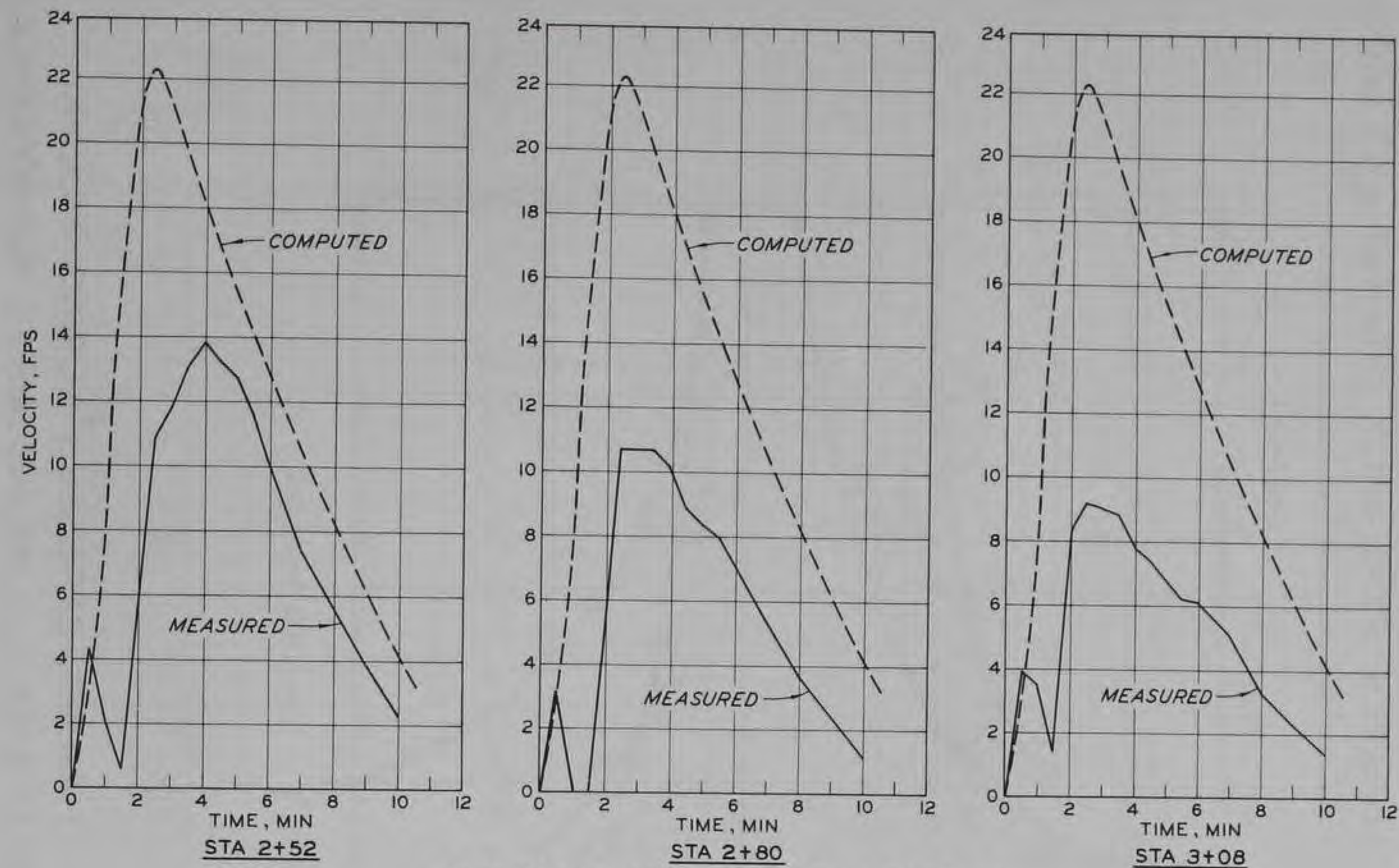


MINIMUM PRESSURES DOWNSTREAM OF FILLING VALVES

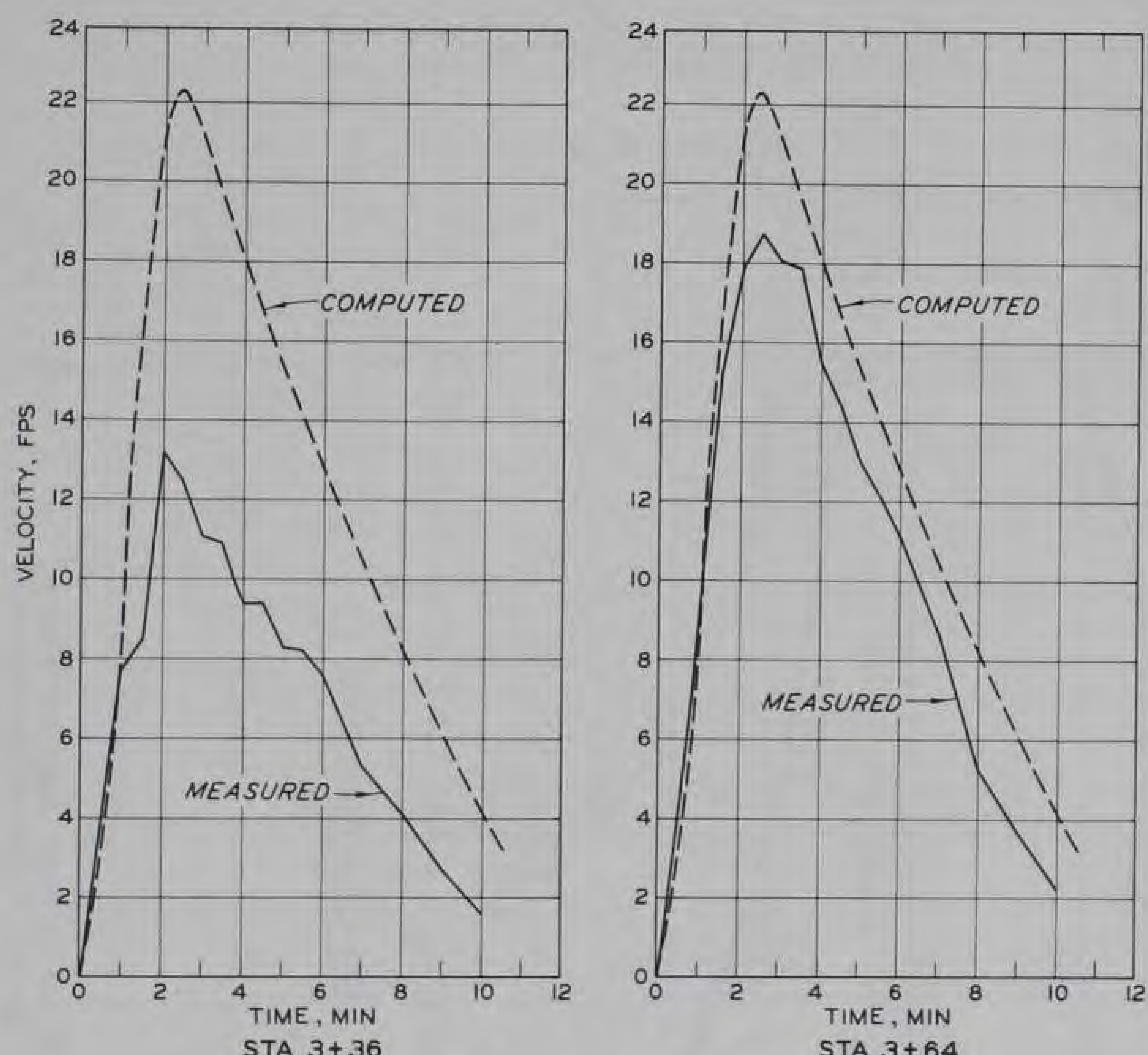
30- AND 40-FT LIFTS



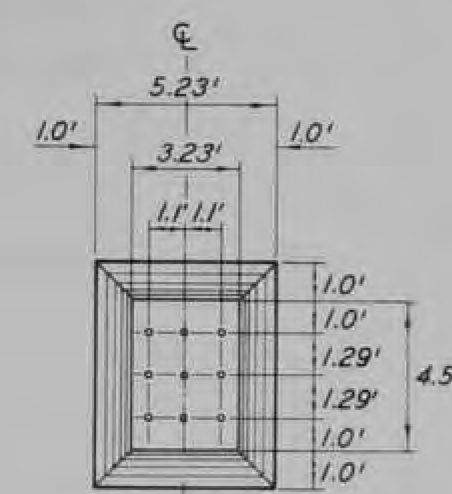
MINIMUM CULVERT PRESSURES



STATION OF MOST UPSTREAM PORT, FT



STATION OF MOST UPSTREAM PORT, FT

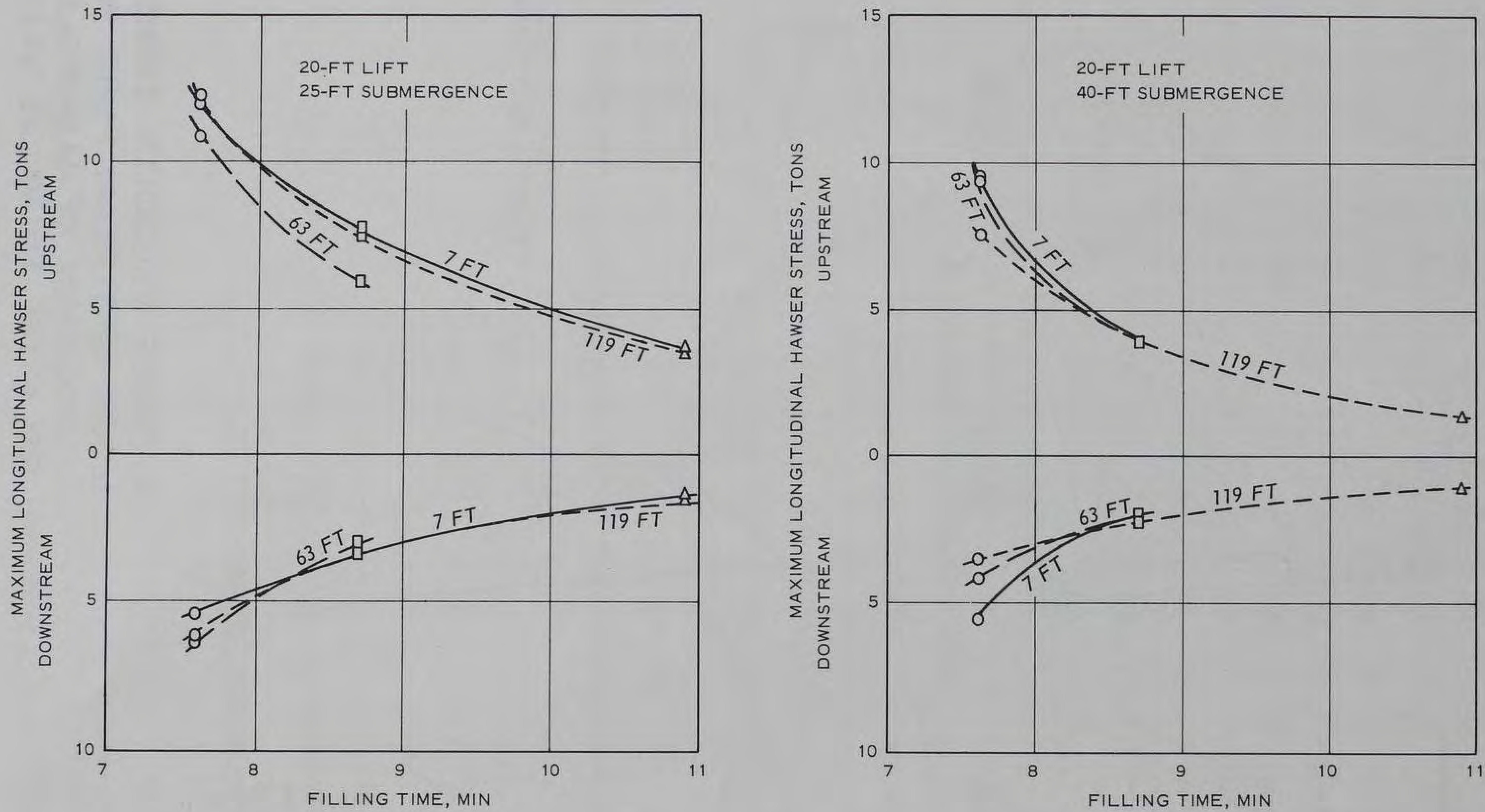


LOCATION OF PORT VELOCITY MEASUREMENT

AVERAGE VELOCITY THROUGH MOST UPSTREAM PORT WITH POSITION OF MANIFOLD RELATIVE TO VALVE VARIED

2-MIN VALVE

40-FT LIFT   30-FT SUBMERGENCE

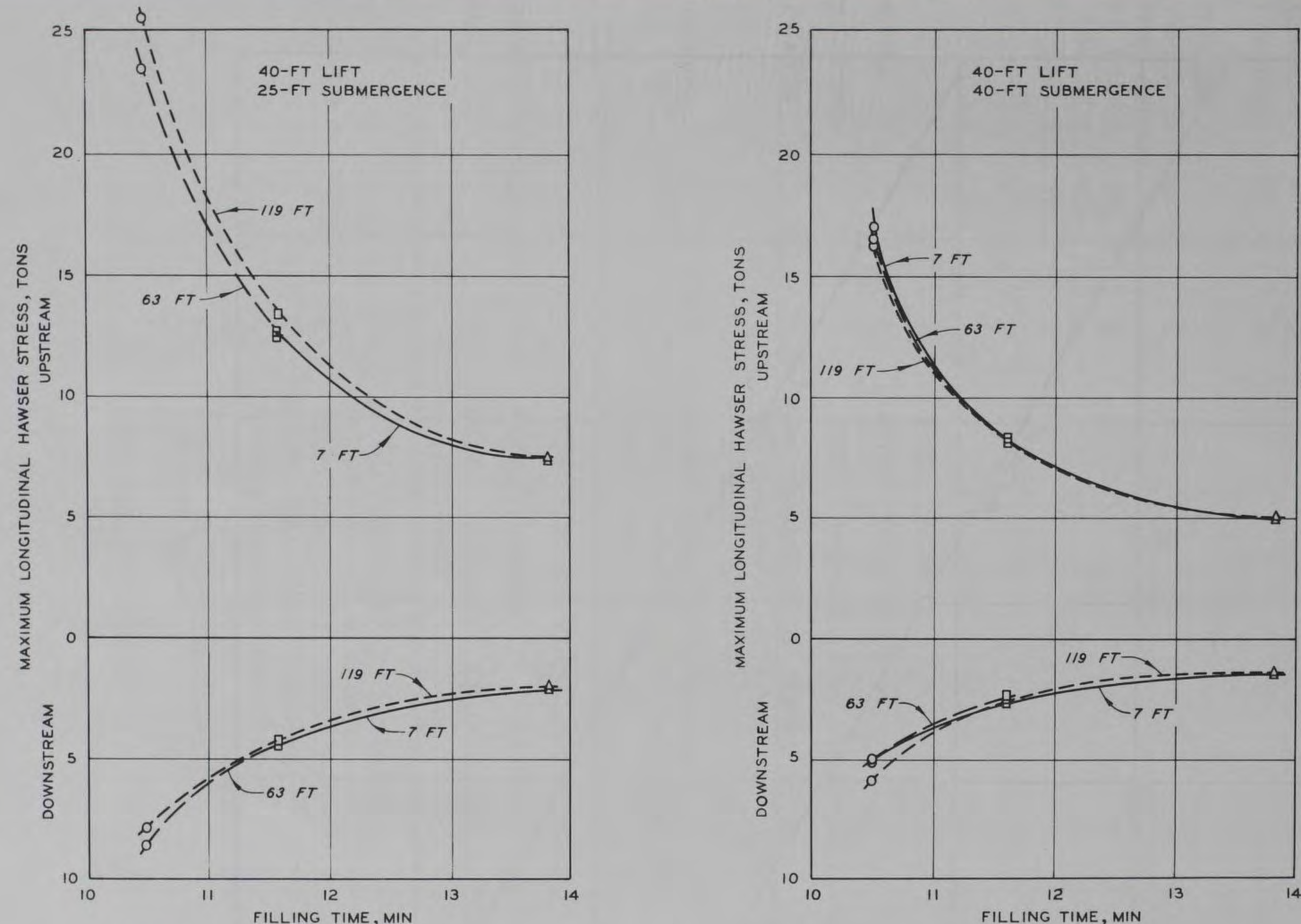


LEGEND

- O 2-MIN VALVE
- □ 4-MIN VALVE
- Δ 8-MIN VALVE

NOTE: DISTANCES SHOWN ON CURVES ARE BETWEEN FILLING VALVE AND MOST UPSTREAM PORT.

HAWSER STRESSES DURING FILLING
20-FT LIFT 25- AND 40-FT SUBMERGENCE



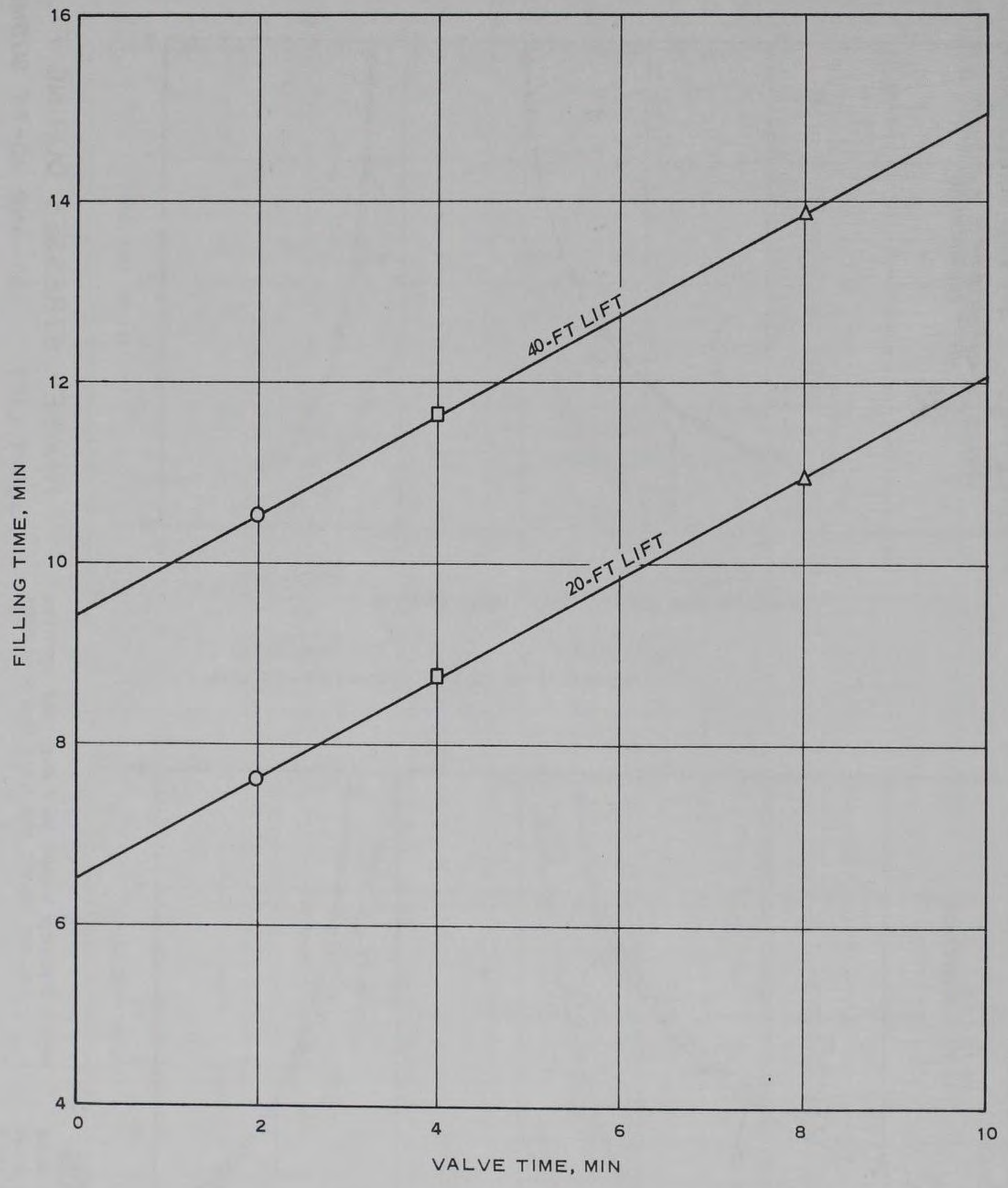
LEGEND

O 2-MIN VALVE
□ 4-MIN VALVE
Δ 8-MIN VALVE

NOTE: DISTANCES SHOWN ON CURVES ARE BETWEEN FILLING VALVES AND MOST UPSTREAM PORT

HAWSER STRESSES DURING FILLING

40-FT LIFT 25- AND 40-FT SUBMERGENCE



FILLING TIMES
FOR 20- AND 40-FT LIFTS

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13. ABSTRACT

This report presents results of tests to investigate the effect of the relative position of the filling valves and port manifold on lock filling characteristics in a sidewall port system for a 110- by 1200-ft lock. These tests are supplemental to generalized tests on a lock of this size (Cannelton Main Lock, Ohio River). Pressure and flow distribution data revealed that the most upstream port in the manifold must be at least 6.5 times the culvert height downstream from the filling valve in order to have this port out of the low pressure zone created by the valve. However, with as many as four ports in the low pressure zone no differences in filling time or hawser stresses could be detected from those obtained with the entire manifold downstream from the low pressure zone.

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