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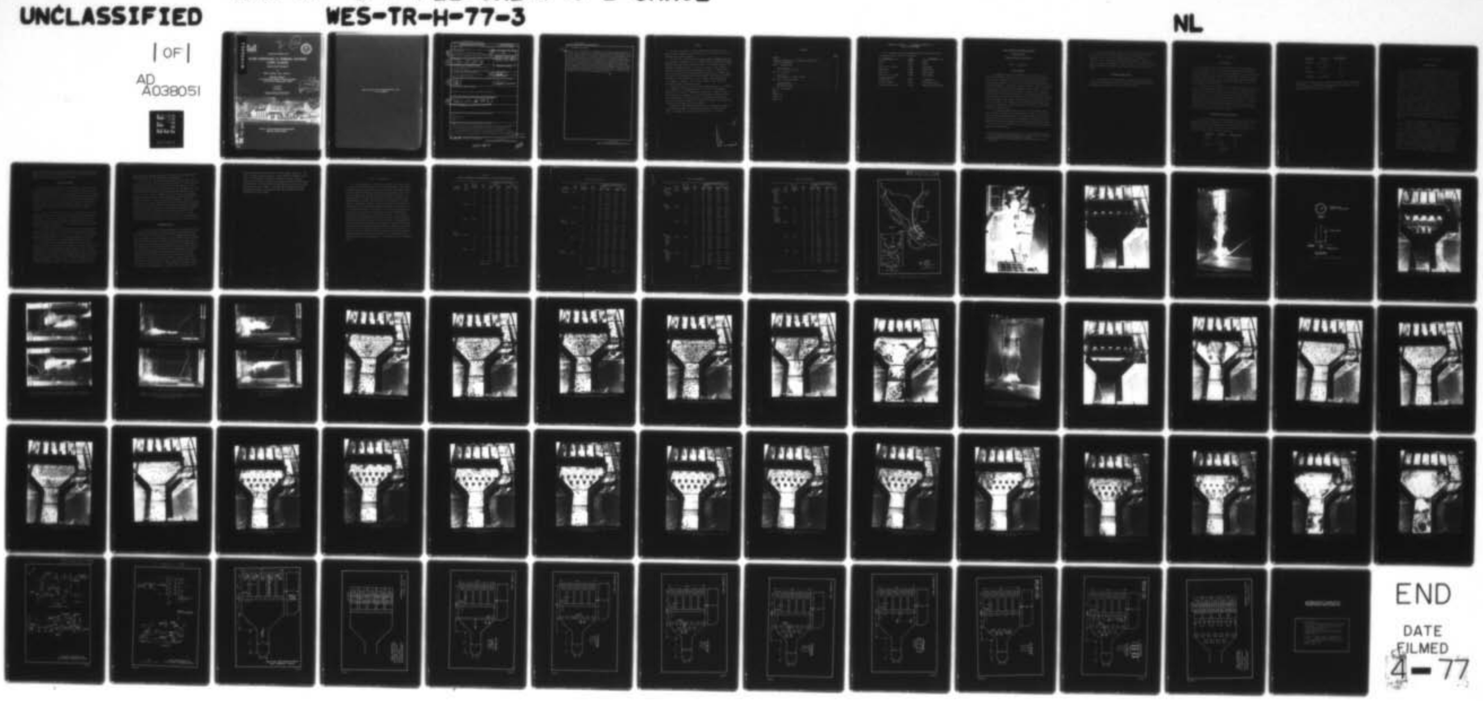

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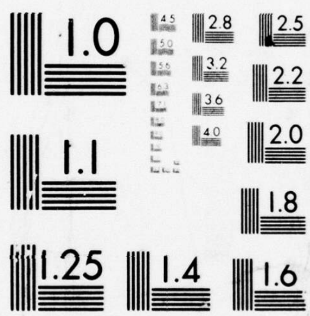

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TECHNICAL REPORT H-77-3

FLOW CONDITIONS AT PUMPING STATIONS
CAIRO, ILLINOIS

Hydraulic Model Investigation

by

Bobby P. Fletcher, John L. Grace, Jr.

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
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March 1977

Final Report

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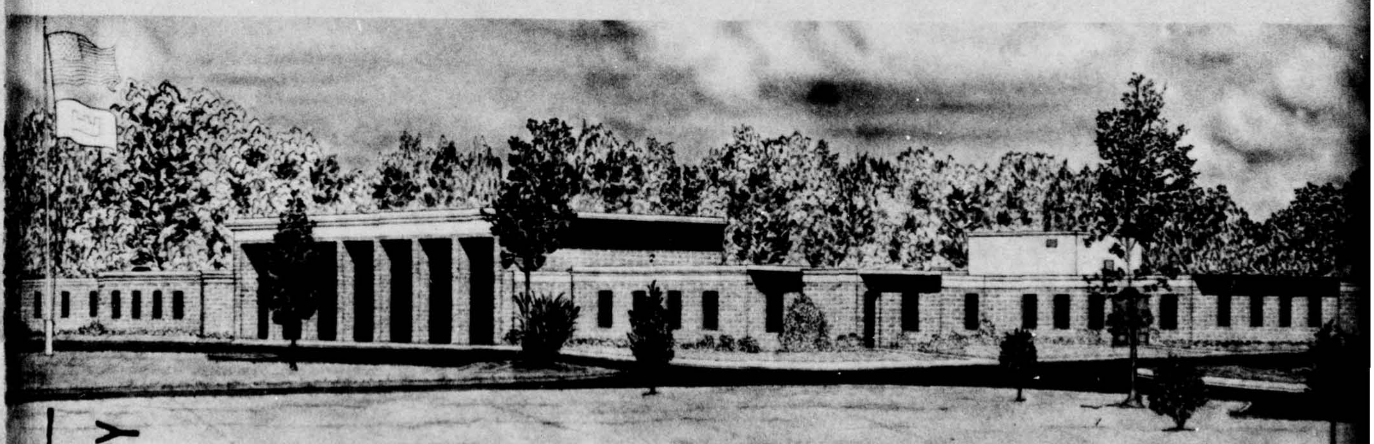

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The model study reported herein was conducted to evaluate the characteristics of inflow to the original design sump and to develop modifications required for improving the distribution of flow to the pump intakes.

The study indicated the need for certain minor modifications to improve flow characteristics in the forebay and ensure satisfactory flow characteristics and pressures near the pump intakes. The major problems encountered were → next page

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20. ABSTRACT (Continued).

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generated by the concentrated, submerged jet entering and passing through the forebay. The concentrated jet emerging from the approach conduit into the forebay produced adverse currents and turbulence near the pump intakes. Satisfactory approach flows were obtained by installing 6-ft-high baffles in the forebay and rounded pier noses at the entrance to the individual pump bays. The baffles were effective in dispersing the jet entering the forebay and the rounded pier noses eliminated the instability and separation of flow at the entrance to the pump bays. The improved flow distribution eliminated the vapor cavity and certain potential for cavitation damage in the pump intakes. The recommended design provided satisfactory flow performance with all combinations of pump operation and anticipated sump elevations. Maximum pressure fluctuations were reduced from about 32 ft of water with the original design to about 5 ft of water with the recommended design.

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PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers, on 14 May 1975, at the request of the U. S. Army Engineer District, Memphis.

The study was conducted during the period May to November 1975 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Structures Division, and under the direct supervision of Mr. J. P. Bohan, past Chief of the Spillways and Channels Branch, and Mr. N. R. Oswalt, present Chief of the Spillways and Channels Branch. The engineer in immediate charge of the model was Mr. B. P. Fletcher, assisted by Messrs. F. L. Hebron, B. Beard, H. Price, and B. Perkins. This report was prepared by Messrs. Fletcher and Grace.

During the course of the model investigation, Messrs. C. E. Thomas, H. E. Wardlaw, J. M. Pendergrass, and G. C. Miller of the Memphis District, and L. Cook, J. McCormick, J. Harz III, I. Behr, W. Hill, D. Armstrong, and H. Walker of the Lower Mississippi Valley Division and J. Robertson of the Office, Chief of Engineers, visited WES to discuss the program of model tests, observe the model in operation, and correlate test results with design studies.

Directors of WES during the conduct of the study and the preparation and publication of the report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	0.0254	meters
feet	0.308	meters
miles (U. S. statute)	1.609	kilometers
square feet	0.093	square meters
cubic feet	0.028	cubic meters
gallons (U. S. liquid)	0.0038	cubic meters
pounds (force) per square inch	6.894	kilopascals
feet per second	0.305	meters per second
cubic feet per second	0.028	cubic meters per second

FLOW CONDITIONS AT PUMPING STATIONS

CAIRO, ILLINOIS

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Two pumping stations are proposed for construction, one at 10th Street and one at 28th Street, in the city of Cairo, Illinois, on the Ohio River (Figure 1). Each station will have five pumps and a total pumping capacity of 65 cfs.* The two stations will have almost identical geometries. The general location, profile, plans, and details of the 10th Street station are presented in Plates 1 and 2. The combined pumping capacity of the two proposed stations will be approximately equal to the combined capacities of the three existing stations at 38th, 28th, and 10th Streets (Figure 1). The three existing stations will be abandoned. The outlets will be designed to pump flows when the stage of the Ohio River exceeds el 28.** The 22nd Street Pumping Station that discharges into the Mississippi River (Figure 1) will remain operable for emergency use.

2. The proposed pumping stations will be of the wet-pit (sump) type and employ vertical shaft, mixed-flow-type pumps to discharge combined storm and sanitary sewerage. Each pump intake will be isolated by divider walls and a 3- by 3-ft gated opening. The pumps will discharge into an elevated chamber that will provide gravity flow through a pipe to the river. Flap valves will be provided on the pump discharge lines to prevent backflow.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

** All elevations (el) cited herein are in feet referenced to mean sea level.

3. Under the recommended plan of the pollution abatement project, all "first flush" flow will be pumped to a new storage lagoon. The lagoon will be designed for a holding capacity of 7,000,000 gal (935,900 cu ft). Approximately 4 hr will be required to fill the lagoon, if empty, when pumping at a rate of 65 cfs. After the first flush, pumping or gravity discharge will be permitted directly to the Ohio River.

Purpose of Model Study

4. The model study was conducted to evaluate the characteristics of inflow to the original sump and to develop modifications required for improving the distribution of flow to the pump intakes.

PART II: THE MODEL

Description

5. The model of the Cairo Pumping Stations was constructed to a linear scale ratio of 1:4. The model was fabricated of transparent plastic and included 20 ft of the approach conduit, the trash rack chamber, sump forebay, gravity passage, gated openings, pump sump, and pump intakes (Figure 2 and Plate 2). Flow through each intake was provided by individual suction pumps which permitted simulation of various flow rates through one or more pumps.

6. Water used in the operation of the model was stored and recycled in a head-box and discharges were measured by turbine flow meters. Water surface elevations were measured by staff gages and electronic surface detectors. Velocities were measured with a pitot tube and a turbine current meter. Current patterns were determined by dye injected into the water and confetti sprinkled on the water surface. Pressure fluctuations at the pump intakes were measured by 0.5-in.-diam, electronic pressure cells flush with the floor of the sump directly below the vertical center line of the pump column.

Interpretation of Model Results

7. Accepted equations of hydraulic similitude, based upon Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype. The general relations expressed in terms of the model scale or length ratio, L_r, are presented in the following tabulation:

Dimension	Ratio	Scale Relation
Length	L_r	1:4
Area	$A_r = L_r^2$	1:16
Velocity	$V_r = L_r^{1/2}$	1:2

(Continued)

Dimension	Ratio	Scale Relation
Discharge	$Q_r = L_r^{5/2}$	1:32
Time	$T_r = L_r^{1/2}$	1:2
Pressure	$P_r = L_r$	1:4
Frequency	$f_r = 1/L_r^{1/2}$	1:0.5

Measurements of discharge, water surface elevations, heads, velocities, and pressure can be transferred quantitatively from the model to prototype equivalents by these scale relations.

PART III: TESTS AND RESULTS

Original Design

8. Details of the original design are presented in Plate 2 and Figure 3. With all pumps operating within the minimum sump elevation (el 299.0) and the maximum sump elevation (el 304), flow exiting the conduit remained concentrated in the center of the forebay. As the submerged jet reflected off the transverse wall in the sump, eddies developed on each side of the forebay (Photos 1-6). Surface currents are indicated by confetti and all photographs were made with a 4-sec (prototype) time exposure. Lateral currents in these eddies passed normal to the openings and generated adverse currents in the outer sump bays 1, 2, 4, and 5. (The pumps and sump bays are numbered from left to right as indicated in Plate 3.) Dye injected upstream of any one of the pump intakes indicated that adverse currents were circulating completely around the back of the intake and that stagnant areas developed as shown in Plate 3. Approach velocities in the pump bays are shown in Plate 4. Confetti and dye injected on the surface in the vicinity of the pump intakes indicated a tendency for air-entraining vortexes. A vapor cavity was observed directly below each pump intake (Photo 7). Circulation of flow observed inside the intake is indicated by dye in Figure 4.

9. A series of piezometers were installed through the floor of the sump directly below pump intake 1. The piezometers indicated a zone of unstable pressures about 10 in. in diameter (prototype) directly below the intake. The piezometers did not respond fast enough to measure the peak pressure fluctuations, and electronic pressure cells were installed on the floor of the sump directly below each pump intake (Figure 5). The pressure fluctuations were recorded on a strip-chart recorder, and the magnitude of the minimum and maximum fluctuations measured with various sump water surface elevations are listed in Table 1. The pressure fluctuations occurred at a random frequency for all anticipated conditions. Whether operating a single pump or all

pumps, the measurement of negative pressures and relatively large pressure fluctuations reflected the adverse currents and the unstable flow conditions observed in the pump bays and intakes.

Alternate Designs

10. Several baffle designs were investigated to develop one that would uniformly distribute water to the pump intakes. The model indicated that a small variation in the current pattern in the forebay would significantly affect currents and pressures approaching the pump intakes. The type 1 baffle (Plate 5, Photo 8) was effective in providing good flow distribution in the sump and reducing the pressure fluctuations at the pump intakes when all pumps were operating (Table 1, Photos 9-13). However, only a slight improvement was observed with single-pump operation.

11. One row of 4-ft-high baffles (type 2 baffles) was installed as shown in Plate 6 to more effectively spread the jet as it emerged from the conduit. The overall performance of the sump was improved by the baffles; however, they did not produce sufficient resistance to adequately spread the submerged jet. Pressure fluctuations below the pump intakes are indicated in Table 1.

12. The type 3 baffle design consisted of two rows of 4-ft-high baffles as shown in Plate 7. The two rows of baffles were effective in spreading the lower portion of the jet as it exited the inflow conduit; however, the upper portion of the jet passed unimpeded over the tops (el 297.5) of the baffles at the minimum sump elevation of 299.0.

13. The baffles were increased in height to el 299.5 (type 4 baffles, Plate 8), and they provided sufficient resistance to adequately spread the jet with all anticipated sump elevations. With all pumps operating, flow in the pump bays was evenly distributed as it approached and entered the pump intakes. With individual pumps operating, uneven flow distribution in the approach and around the periphery of the pump intake was observed in pump bays 1 and 5. This is reflected by the pressure fluctuations in Table 1. The adverse flow conditions in the

pump bays and at the pump intakes were caused by the instability and separation of flow at the entrances to the pump bays.

14. The baffles were removed and semicircular pier noses (type 1) were installed at the entrances to the bays (Plate 9) to reduce the flow separation and provide a more stable inflow to the pump bays. With single pump operation, uniform flow was observed in all pump bays. With all pumps operating, adverse flow distribution was observed in pump bays 2, 3, and 4. This was attributed to the unstable, concentrated, submerged jet entering the forebay, and, again, indicated the need for baffles to spread the flow as it entered the forebay. The type 5 baffles (Plate 10) were added but did not provide sufficient resistance to adequately spread the flow when all pumps were operating. The type 4 baffles were reinstalled with type 1 pier noses and flow was well distributed in the bays. However, unstable flow was observed as flow entered the pump bays around the tops of the pier noses. This was eliminated by extending the tops of the pier noses 2 ft above the tops of the entrances to the pump bays (type 2 pier nose, Plate 11, Figure 7).

Recommended Design

15. After evaluating the various designs, it was decided that the best hydraulic performance was provided by the type 4 baffles and the type 2 pier nose (Plate 11, Figure 6). The recommended design eliminated tendencies for air-entraining vortexes, provided uniform approach flow to all pump bays with a minimum of turbulence, and produced good distribution of flow entering the pump intakes for any single pump or any combination of pumps operating with all anticipated sump elevations. With all pumps operating, investigation of currents and water surface elevations downstream from the inflow conduit at the first row of baffles indicated a maximum velocity of 2.2 fps and a 0.1-ft head differential across the front row of baffles. Various flows in the forebay are illustrated in Photos 14-25. Approach velocities in the pump bays are shown in Plate 12. Stagnant areas in the rear corners of the pump bays were eliminated. Dye injected near the bottom of the

pump bay indicated uniform flow into the pump intake (Figure 7). Profiles of flows approaching the No. 1 pump intake are presented in Figure 8. The relatively low pressure fluctuations shown in Table 1 reflect the satisfactory hydraulic performance obtained with the recommended design. Tests conducted with and without the gate slots in the pier noses and access ladders in the pump bays indicated that these appurtenances should not adversely affect the distribution of flow approaching the pump intakes.

PART IV: DISCUSSION

16. The model indicated the need for certain minor modifications to improve flow characteristics in the forebay and ensure satisfactory flow characteristics and pressures in the vicinity of the pump intakes. The major hydraulic problems encountered were generated by the concentrated, submerged jet entering and passing through the forebay. The concentrated jet emerging from the approach conduit into the forebay produced adverse currents and turbulence in the vicinity of the pump intakes. Satisfactory approach flows were obtained by providing 6-ft-high baffles in the forebay and rounded pier noses at the entrances to the individual pump bays. The baffles were effective in dispersing the jet entering the forebay and the rounded pier noses eliminated the instability and separation of flow at the entrances to the pump bays. The improved flow distribution eliminated the vapor cavity and certain potential for cavitation damage in the pump intakes. The recommended design provided satisfactory flow performance with all combinations of pump operation and anticipated sump elevations. Pressure cells located on the floor of the sump directly below the center line of each pump intake reflected the improved flow conditions by indicating a reduction in maximum pressure fluctuations from about 32 ft of water with the original design to only approximately 5 ft of water with the recommended design.

Table 1

Pressure Fluctuation at Pump Intake (13-cfs Discharge per Pump)

Design	Sump El	No. of Pumps Running	Pump No.	Pressure Fluctuation ft-H_2O Max	Pressure Fluctuation ft-H_2O Min	Pressure Fluctuation psi Max	Pressure Fluctuation psi Min
Original	299.0	1	1	+4	-13.6	+1.7	-5.8
		2	2	+4	-5.4	+1.7	-2.3
		3	3	+4	-0.9	+1.7	-0.4
		4	4	+4	-12.4	+1.7	-5.3
		5	5	+4	-19.1	+1.7	-8.2
	299.0	All	1	+4	-28.2	+1.7	-12.1
			2	+4	-14.8	+1.7	-6.4
			3	+4	-4.2	+1.7	-1.8
			4	+4	-17.3	+1.7	-7.4
			5	+4	-23.6	+1.7	-10.1
	304.0	All	1	+9	+4.7	+3.9	+2.0
			2	+9	-4.6	+3.9	-1.9
			3	+9	+3.3	+3.9	+1.4
			4	+9	+1.6	+3.9	+0.7
			5	+9	+1.6	+3.9	+0.7
Type 1 baffle	299.0	1	1	+4	-4.9	+1.7	-2.1
		2	2	+4	-10.3	+1.7	-4.4
		3	3	+4	-0.2	+1.7	-0.1
		4	4	+4	-8.3	+1.7	-3.6
		5	5	+4	-12.6	+1.7	-5.4
	299.0	All	1	+4	-11.6	+1.7	-5.0
			2	+4	-4.2	+1.7	-1.8
			3	+4	-5.0	+1.7	-2.2
			4	+4	-8.4	+1.7	-3.6
			5	+4	-3.9	+1.7	-1.6

(Continued)

(Sheet 1 of 4)

Table 1 (Continued)

Design	Sump El	No. of Pumps Running	Pump No.	Pressure Fluctuation ft-H_2O Max	Min	psi Max	Min
Type 2 baffle	299.0	1	1	+4	-10.4	+1.7	-4.5
		2	2	+4	-4.1	+1.7	-1.8
		3	3	+4	+0.7	+1.7	+0.3
		4	4	+4	-2.6	+1.7	-1.1
		5	5	+4	-15.3	+1.7	-6.6
	299.0	All	1	+4	-12.6	+1.7	-5.4
		"	2	+4	-10.3	+1.7	-4.4
		"	3	+4	-4.2	+1.7	-1.8
		"	4	+4	-18.2	+1.7	-7.9
		"	5	+4	-4.3	+1.7	-1.9
Type 3 baffle	299.0	1	1	+4	-10.4	+1.7	-4.5
		2	2	+4	+0.3	+1.7	+0.1
		3	3	+4	-0.1	+1.7	-0.1
		4	4	+4	-4.2	+1.7	-1.8
		5	5	+4	-11.6	+1.7	-5.0
	299.0	All	1	+4	-1.4	+1.7	-2.3
		"	2	+4	+0.9	+1.7	+0.4
		"	3	+4	-2.6	+1.7	-1.1
		"	4	+4	-4.2	+1.7	-1.8
		"	5	+4	-7.0	+1.7	-3.0
Type 4 baffle	299.0	1	1	+4	-9.7	+1.7	-4.2
		2	2	+4	-4.1	+1.7	-1.8
		3	3	+4	-2.6	+1.7	-1.1
		4	4	+4	-2.6	+1.7	-1.1
		5	5	+4	-11.6	+1.7	-5.0

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(Sheet 2 of 4)

Table 1 (Continued)

Design	Sump El	No. of Pumps Running	Pump No.	Pressure Fluctuation ft-H_2O Max	Min	psi Max	Min
Type 4 baffle (Cont'd)	299.0	All	1	+4	-0.4	+1.7	+0.2
			2	+4	-0.3	+1.7	-0.1
			3	+4	-0.9	+1.7	-0.4
			4	+4	-1.7	+1.7	-0.7
			5	+4	-1.5	+1.7	-0.7
Type 1 pier nose	299.0	1	1	+4	+1.9	+1.7	+0.8
		2	2	+4	+0.3	+1.7	+0.1
		3	3	+4	+2.4	+1.7	+1.0
		4	4	+4	+0.7	+1.7	+0.3
		5	5	+4	+0.3	+1.7	+0.1
	299.0	All	1	+4	+1.8	+1.7	+0.8
			2	+4	-6.5	+1.7	-2.8
			3	+4	-6.6	+1.7	-2.8
			4	+4	-2.2	+1.7	-1.2
			5	+4	+1.2	+1.7	+0.5
Type 5 baffle and type 1 pier nose	299.0	All	1	+4	-5.4	+1.7	-2.4
			2	+4	-6.5	+1.7	-2.8
			3	+4	+0.7	+1.7	+0.3
			4	+4	-0.9	+1.7	-0.4
			5	+4	-4.3	+1.7	-1.8
Type 4 baffle and type 1 pier nose	299.0	1	1	+4	-1.0	+1.7	-0.5
		2	2	+4	-1.0	+1.7	-0.5
		3	3	+4	+1.5	+1.7	+0.6
		4	4	+4	+1.5	+1.7	+0.6
		5	5	+4	-0.6	+1.7	-0.2

(Continued)

(Sheet 3 of 4)

Table 1 (Concluded)

Design	Sump El	No. of Pumps Running	Pump No.	Pressure Fluctuation ft-H_2O Max	Min	psi Max	Min
Type 4 baffle and type 1 pier nose (Cont'd)	299.0	All	1	+4	-1.8	+1.7	-0.5
			2	+4	-1.6	+1.7	-0.4
			3	+4	+1.5	+1.7	+0.6
			4	+4	-2.2	+1.7	-1.2
			5	+4	+0.3	+1.7	+0.1
Type 4 baffle and type 2 pier nose (recommended design)	299.0	1	1	+4	-0.3	+1.7	-0.1
		2	2	+4	+0.3	+1.7	+0.1
		3	3	+4	+0.7	+1.7	+0.3
		4	4	+4	+0.7	+1.7	+0.3
		5	5	+4	+1.2	+1.7	+0.5
	299.0	All	1	+4	+1.0	+1.7	+0.5
			2	+4	-0.3	+1.7	-0.1
			3	+4	0	+1.7	-0.1
			4	+4	0	+1.7	-0.1
			5	+4	+0.3	+1.7	+0.1
	304	All	1	+9	+6.1	+3.9	+2.6
			2	+9	+5.9	+3.9	+2.5
			3	+9	+5.8	+3.9	+2.5
			4	+9	+6.0	+3.9	+2.5
			5	+9	+6.0	+3.9	+2.5
	302	All	1	+7	+4.0	+3.0	+1.7
			2	+7	+4.1	+3.0	+1.8
			3	+7	+4.0	+3.0	+1.7
			4	+7	+3.9	+3.0	+1.7
			5	+7	+3.8	+3.0	+1.6

(Sheet 4 of 4)

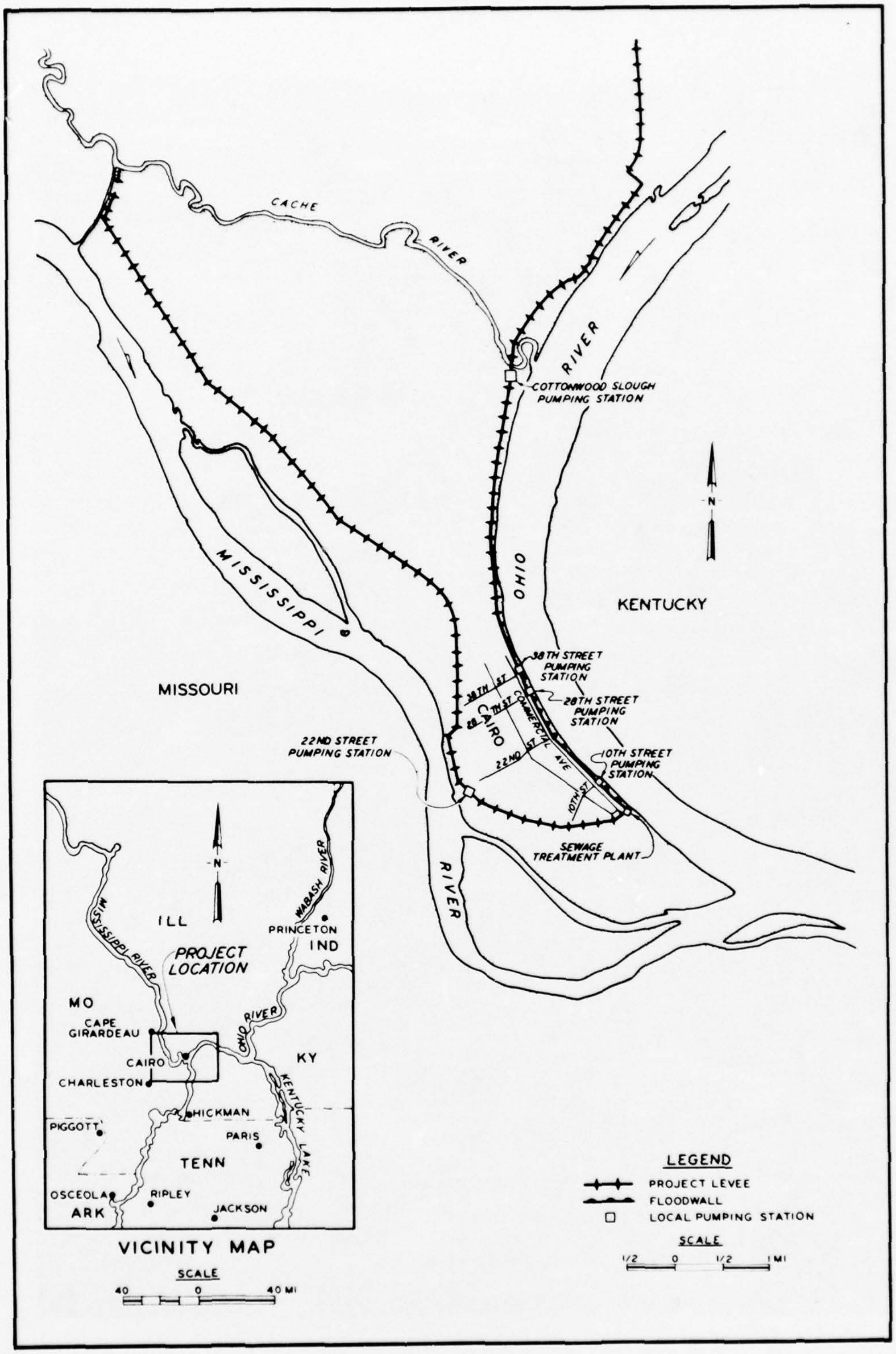


Figure 1. Project location and vicinity map

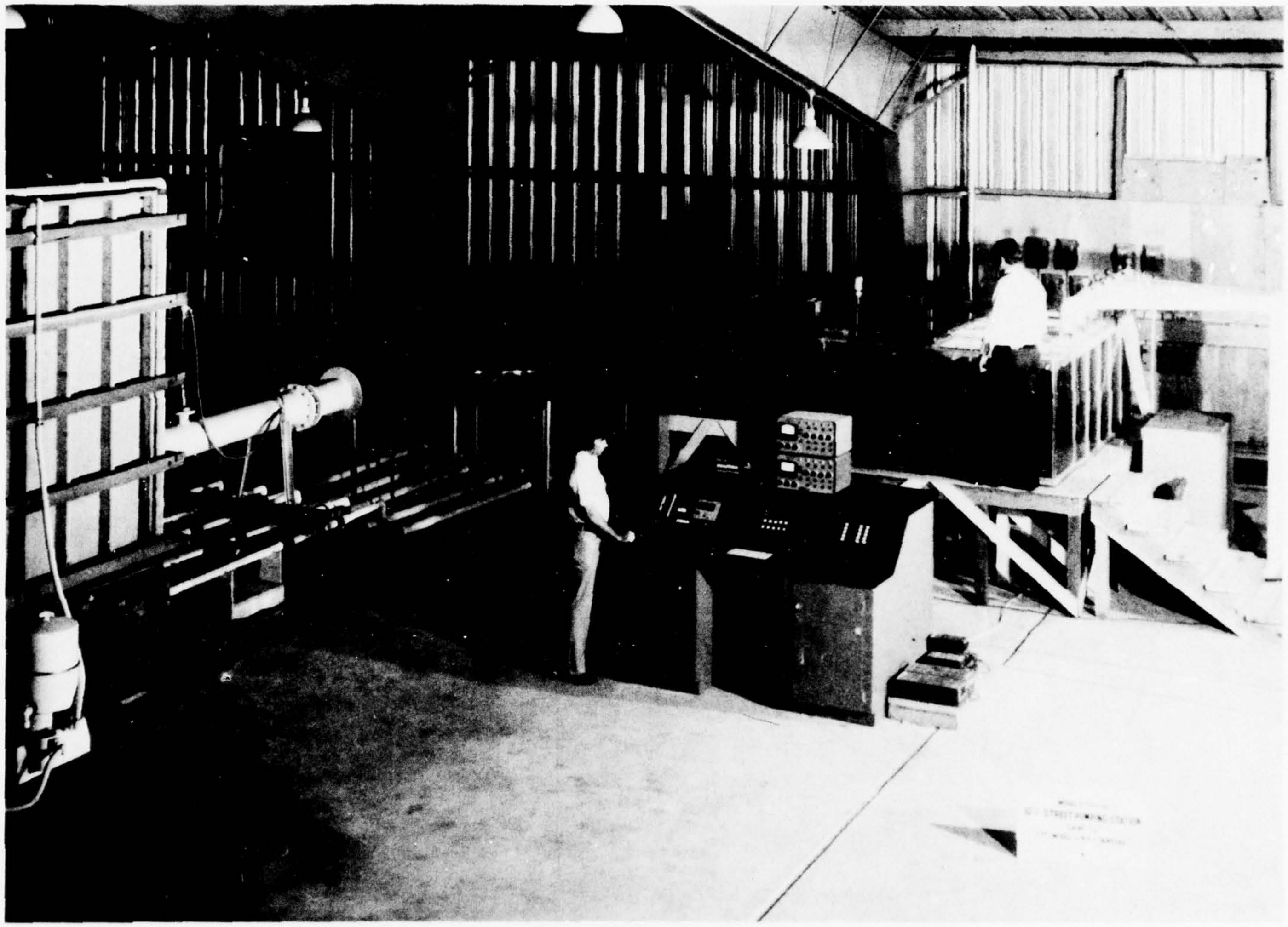


Figure 2. The 1:4-scale model

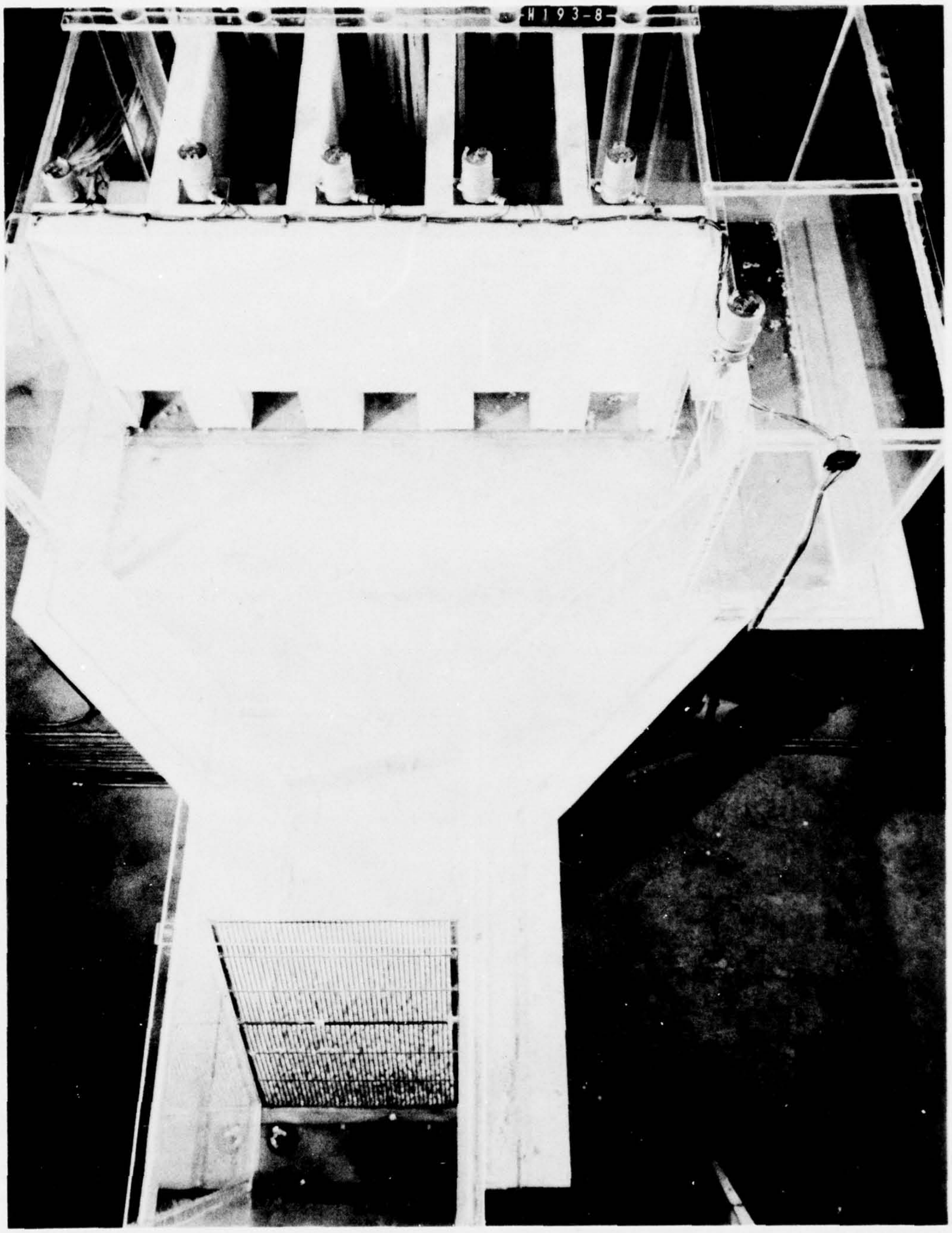


Figure 3. Plan of original design pumping station

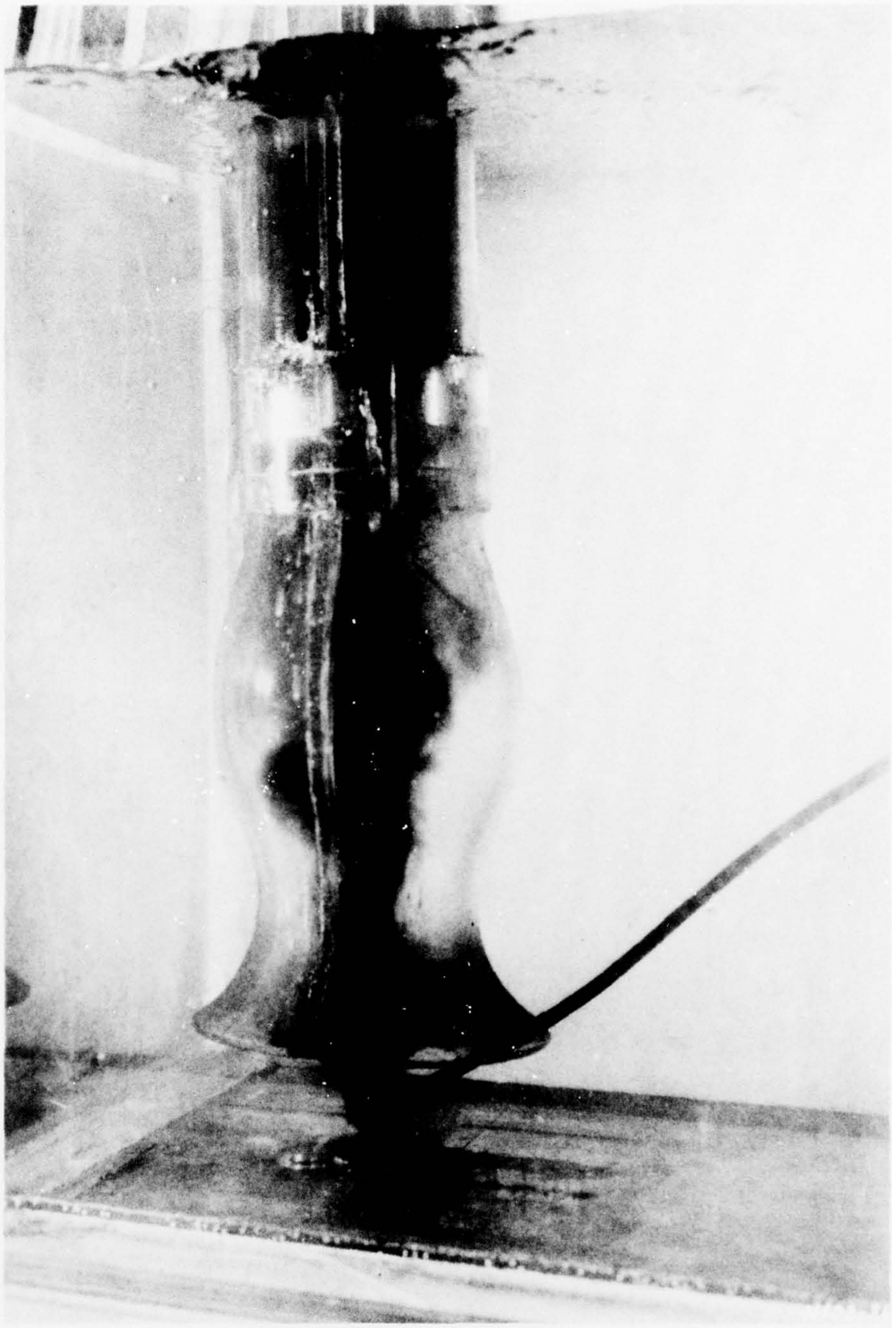


Figure 4. Flow circulation inside intake; original design sump, sump el 299.0, all pumps discharging (discharge, 13 cfs per pump)

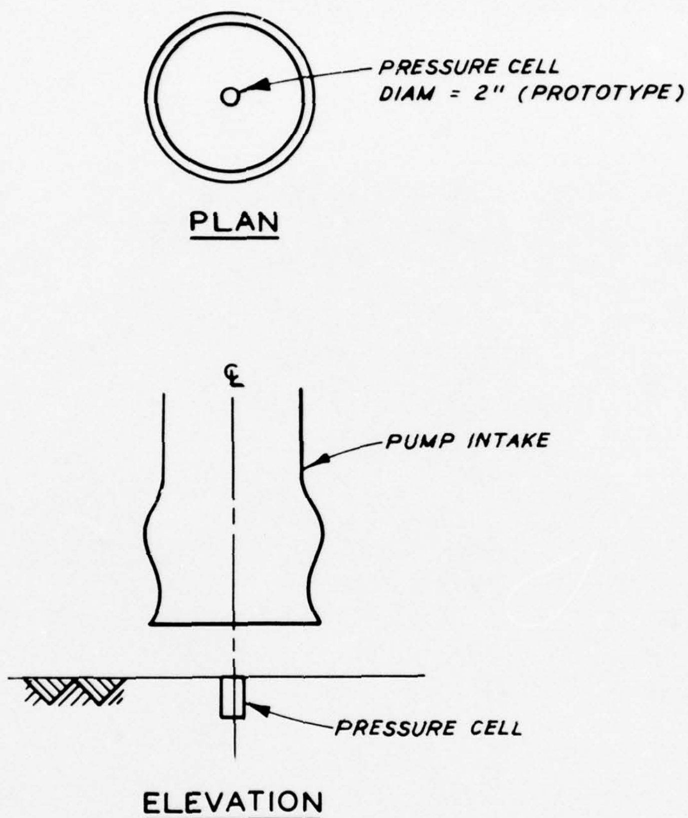


Figure 5. Pressure cell location

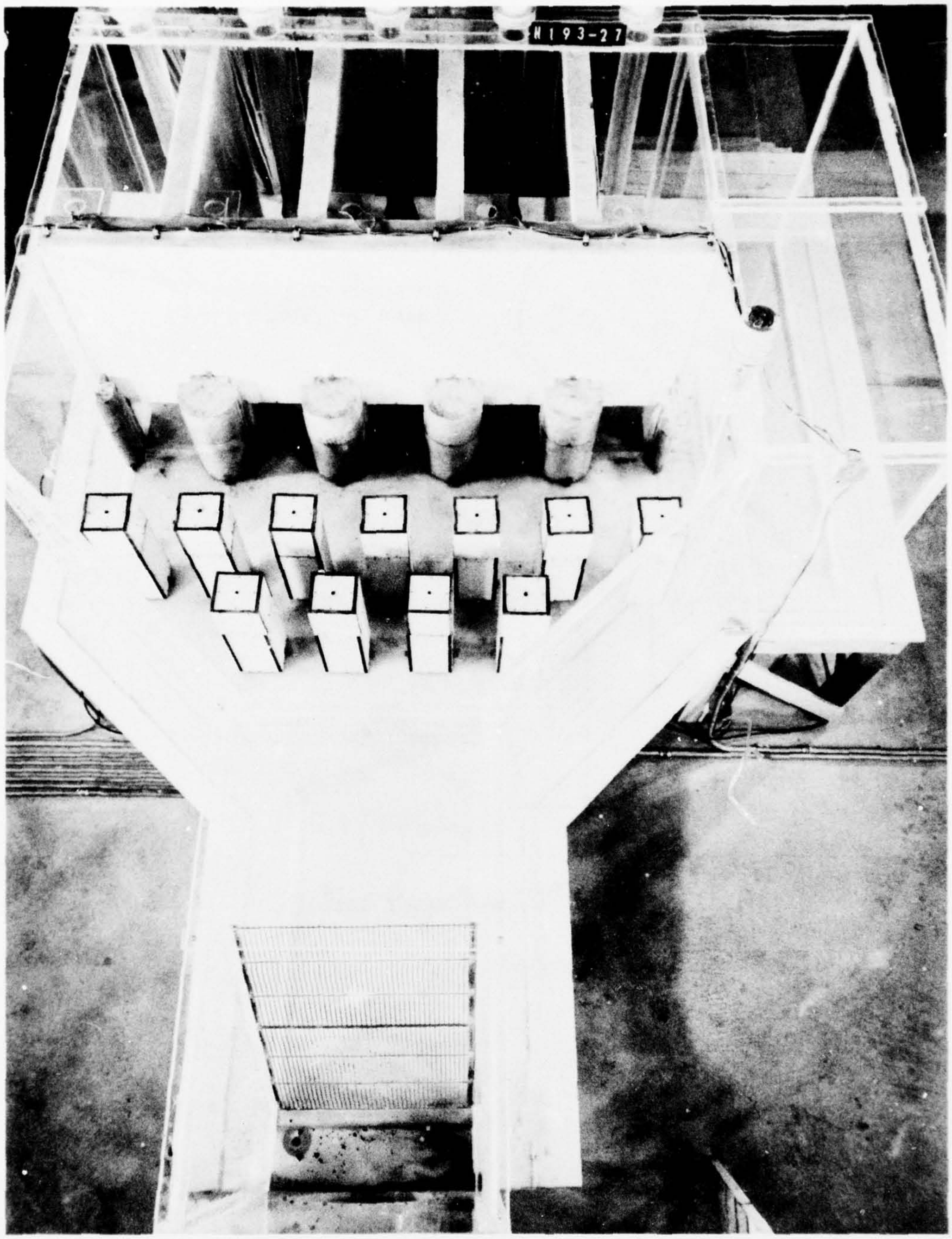
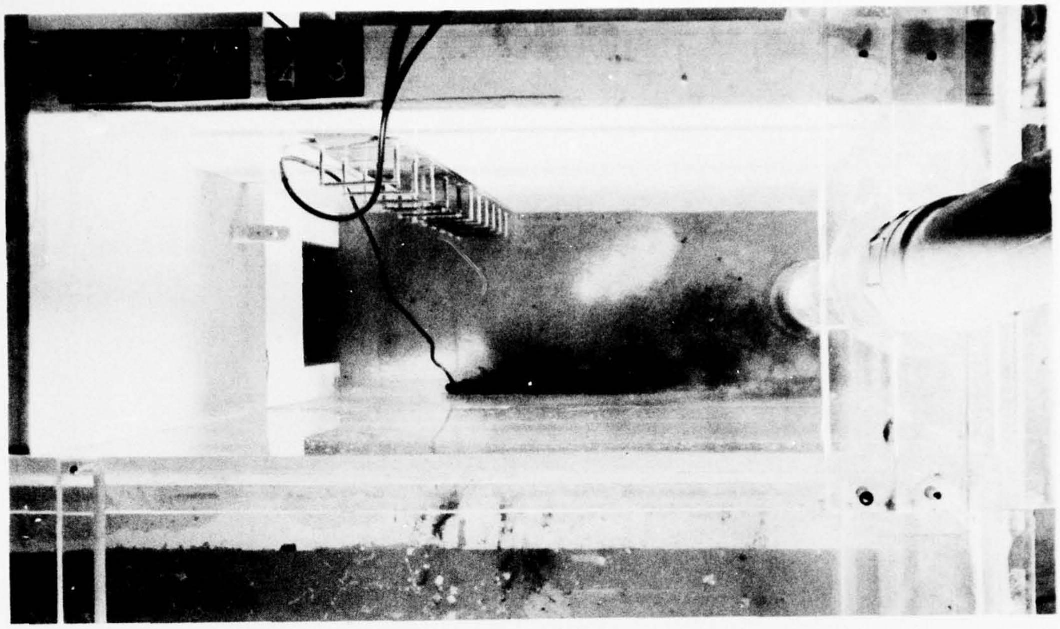
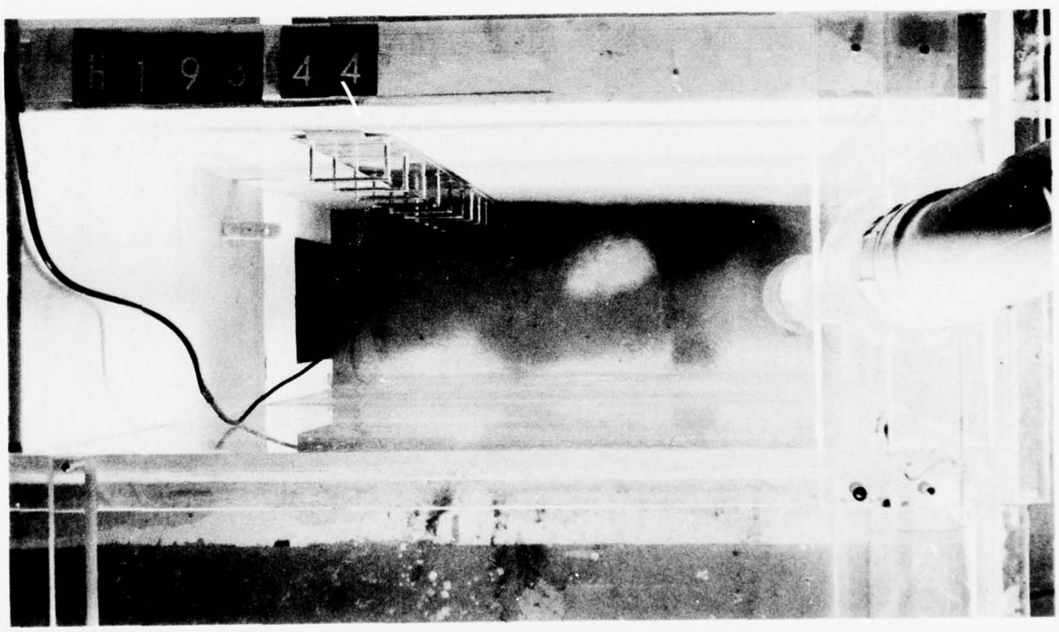


Figure 6. Type 4 baffles, type 2 pier nose (recommended design)

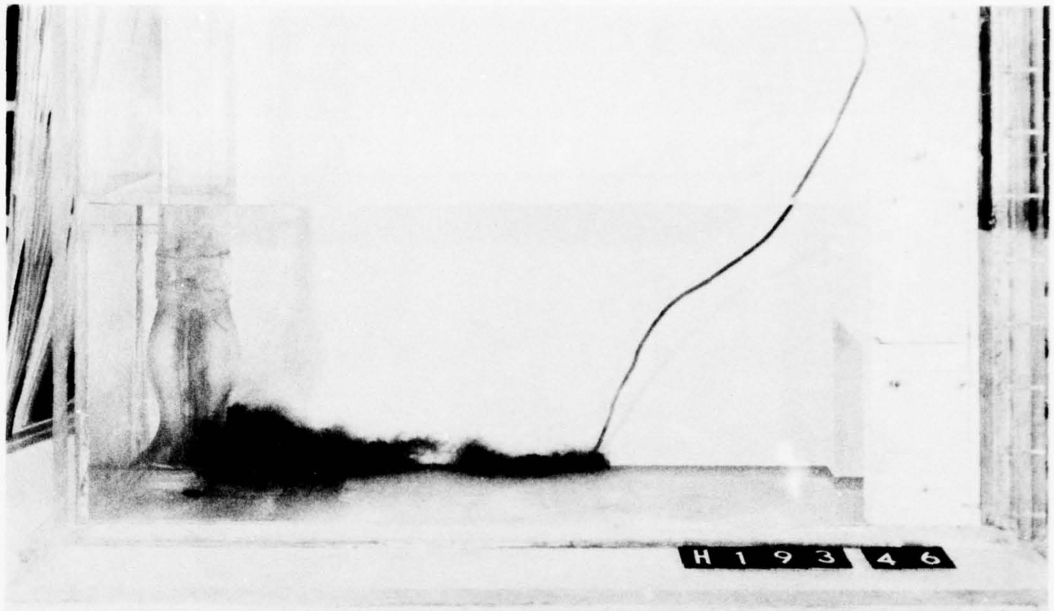


a. Dye injected near right side

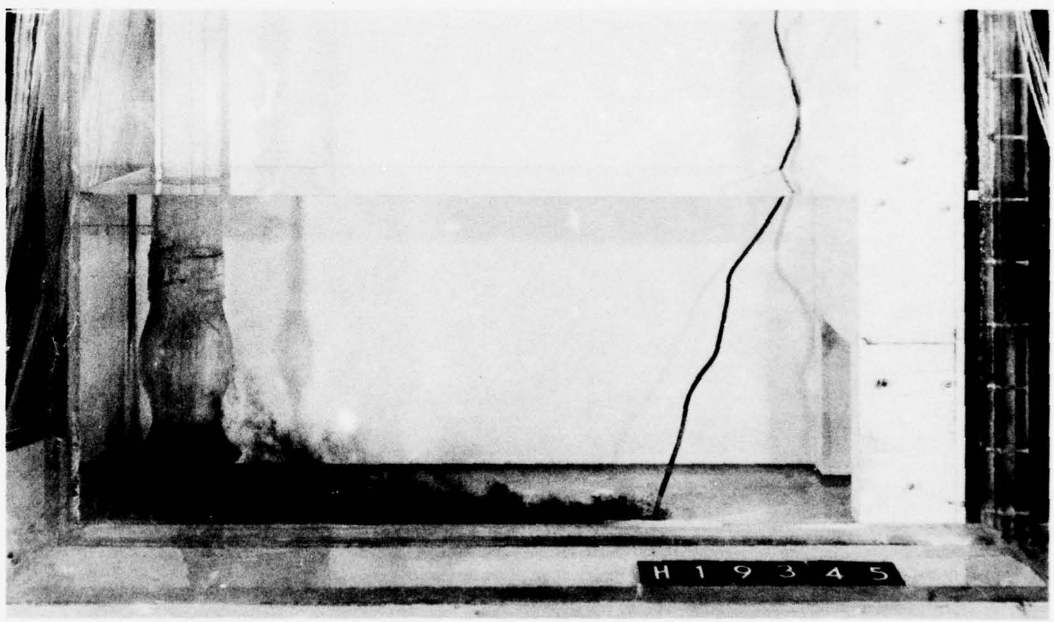


b. Dye injected near left side

Figure 7. Currents approaching No. 1 pump intake. Recommended design, all pumps operating (discharge per pump, 13 cfs), sump el 299.0

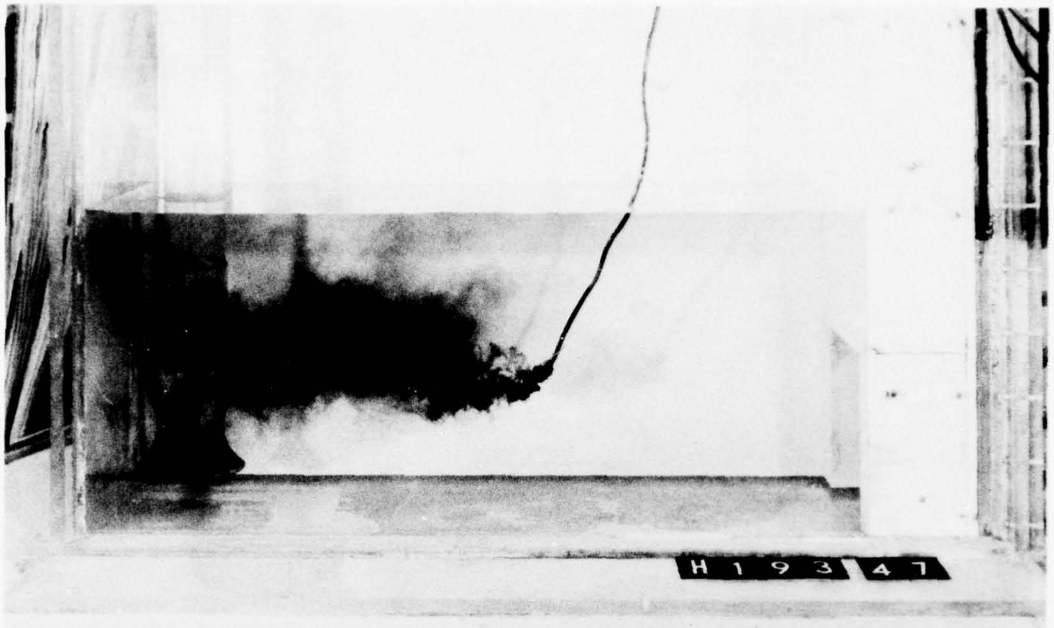


a. Dye injected on bottom near right side

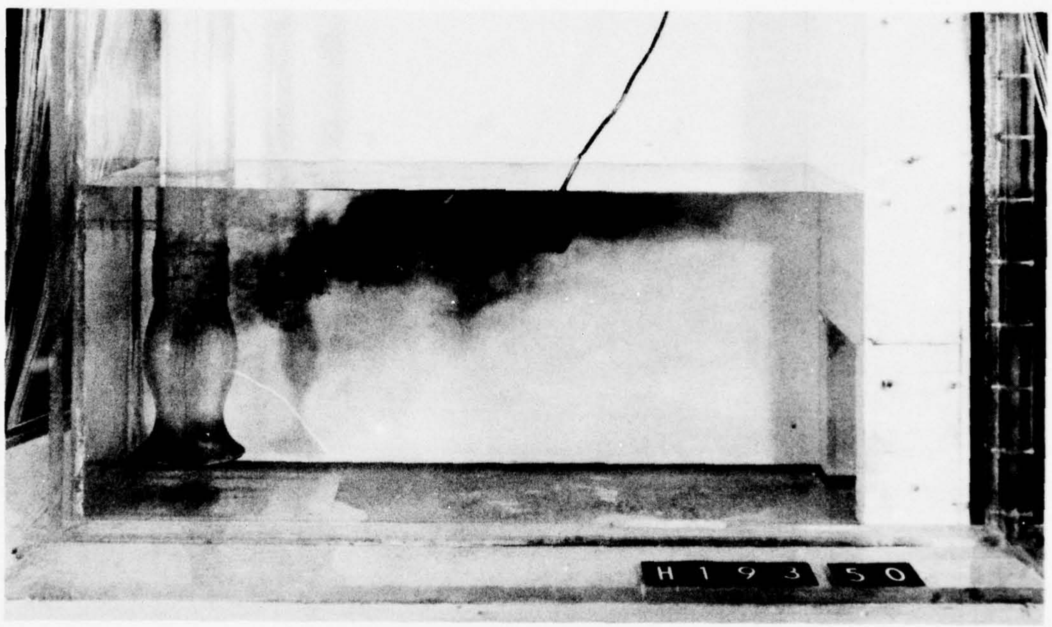


b. Dye injected on bottom near left side

Figure 8. Flow profiles, currents approaching No. 1 sump intake. Recommended design, all pumps operating (discharge per pump, 13 cfs), sump el 299.0 (sheet 1 of 2)



c. Dye injected near middepth



d. Dye injected near surface

Figure 8 (Sheet 2 of 2)

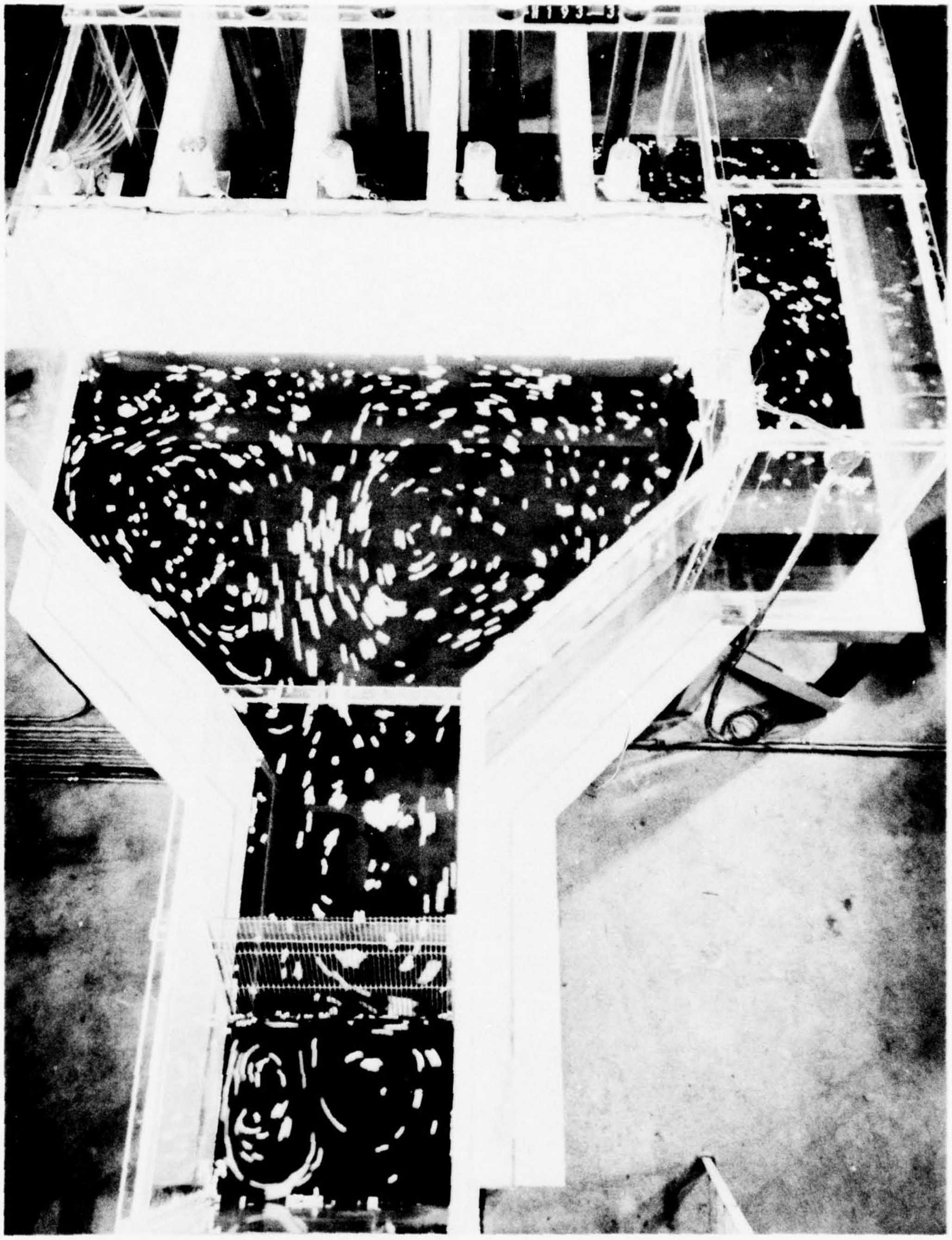


Photo 1. Flow conditions; pump 1 operating, sump el 299.0

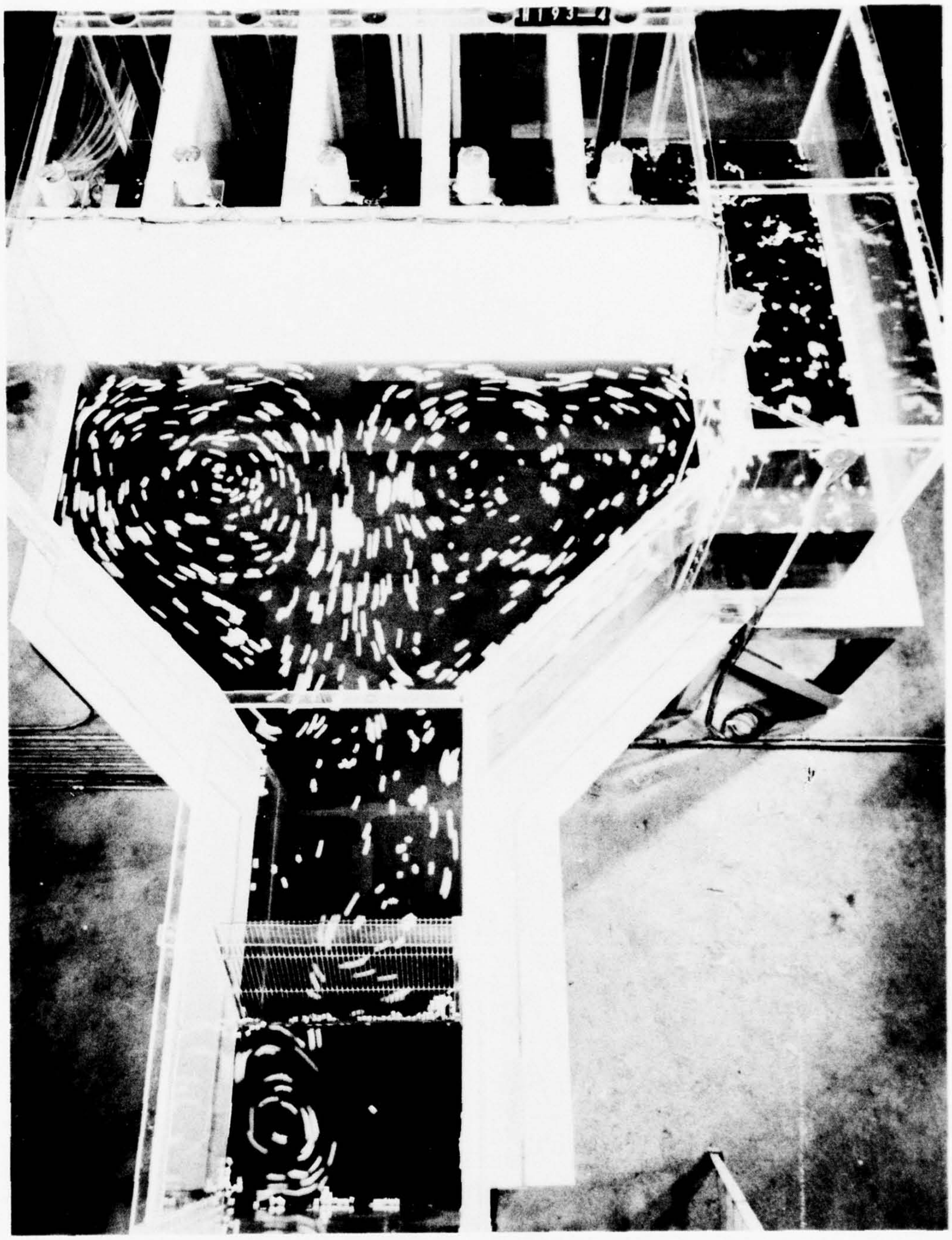


Photo 2. Flow conditions; pump 2 operating, sump el 299.0

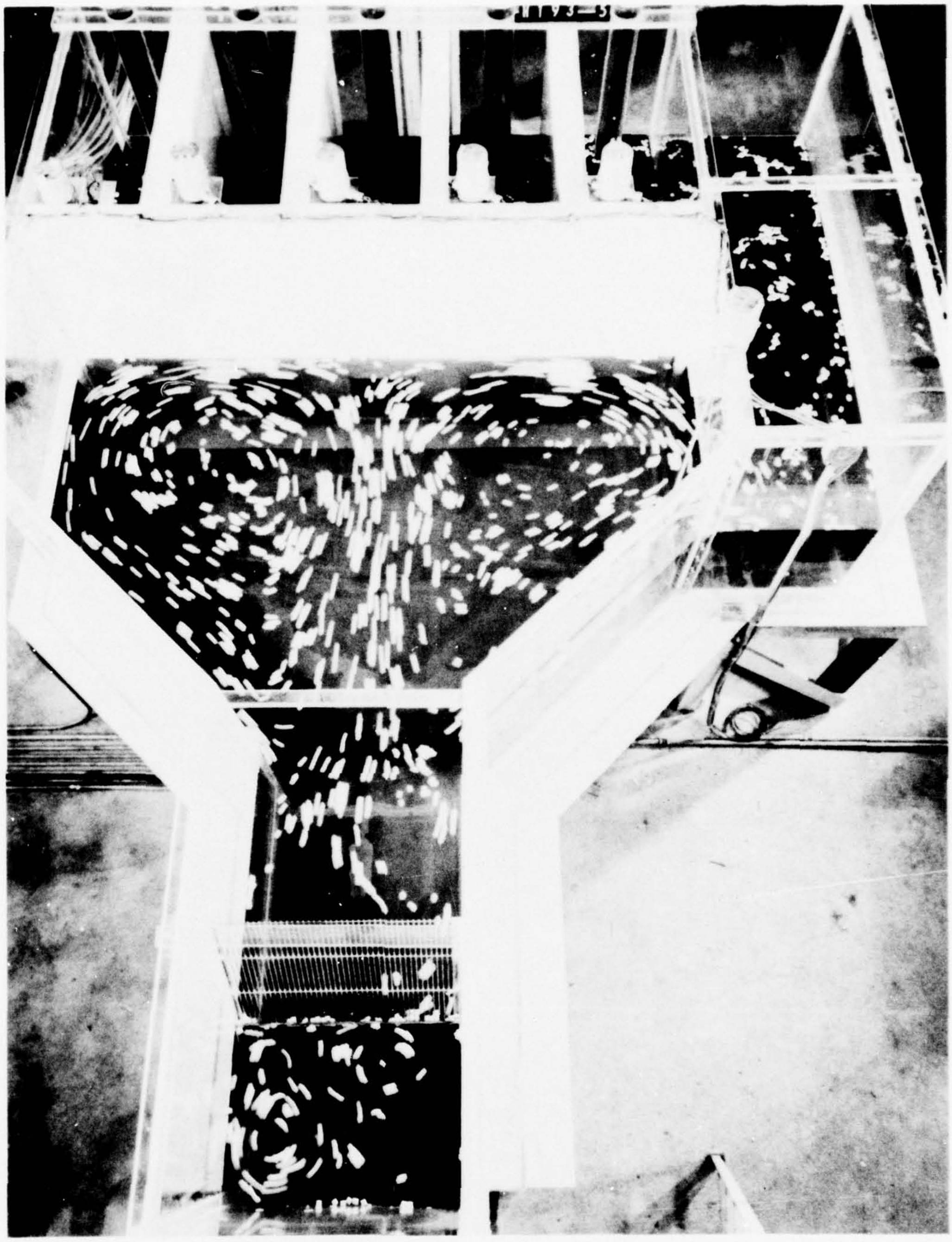


Photo 3. Flow conditions; pump 3 operating, sump el 299.0

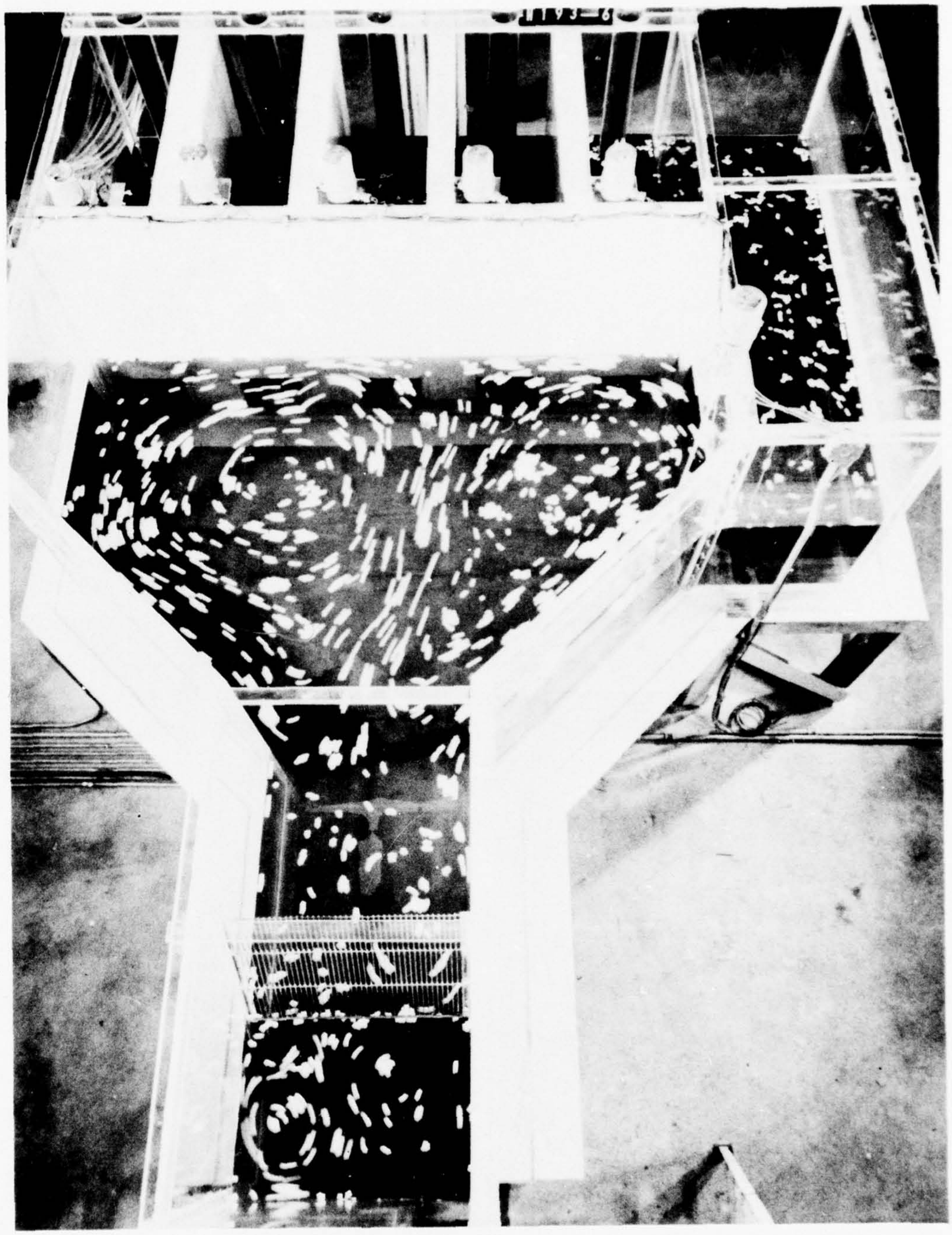


Photo 4. Flow conditions; pump 4 operating, sump el 299.0

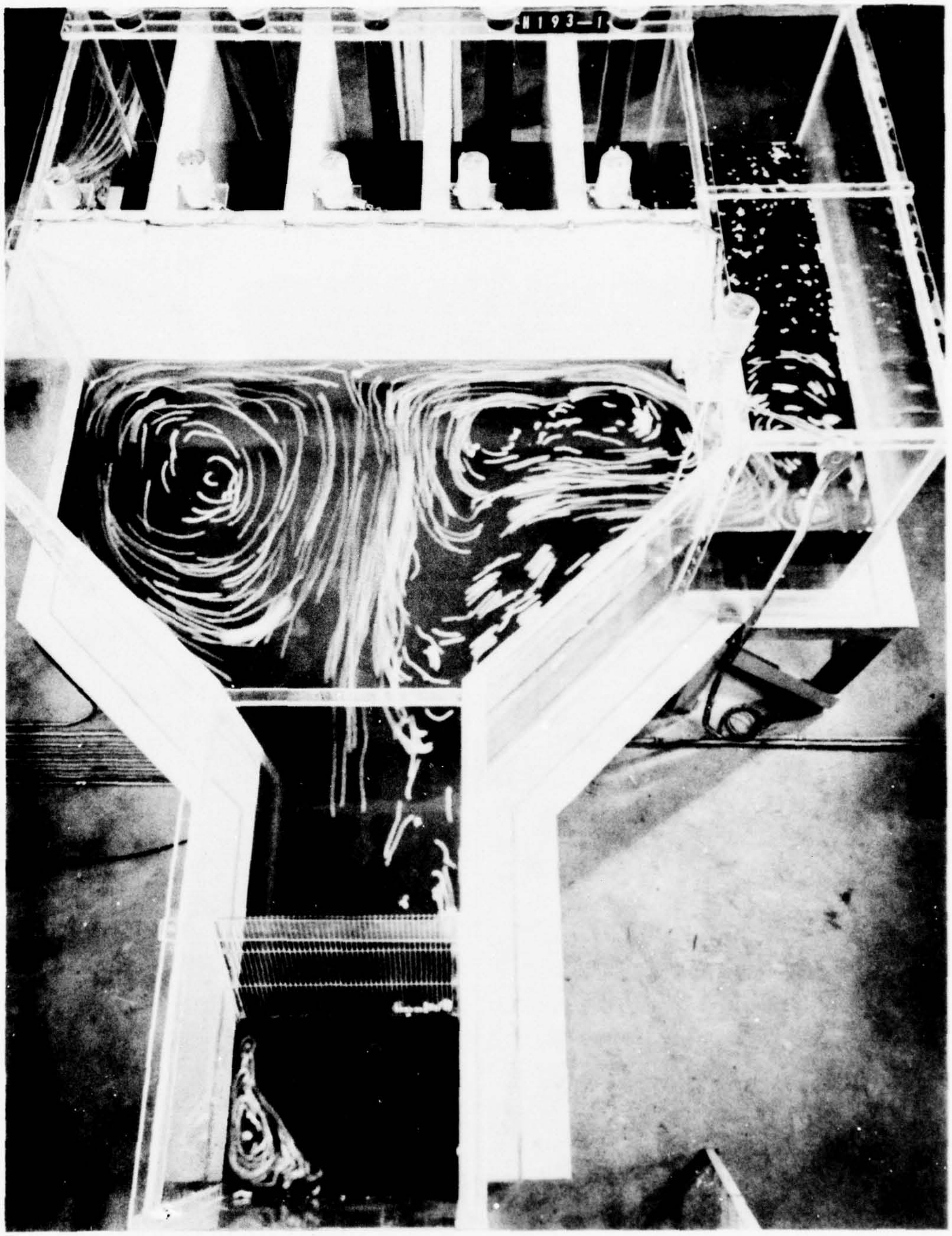


Photo 5. Flow conditions; pumps 1-5 operating, sump el 299.0

Photo 6. Flow conditions; pumps 1-5 operating, sump el 304.0

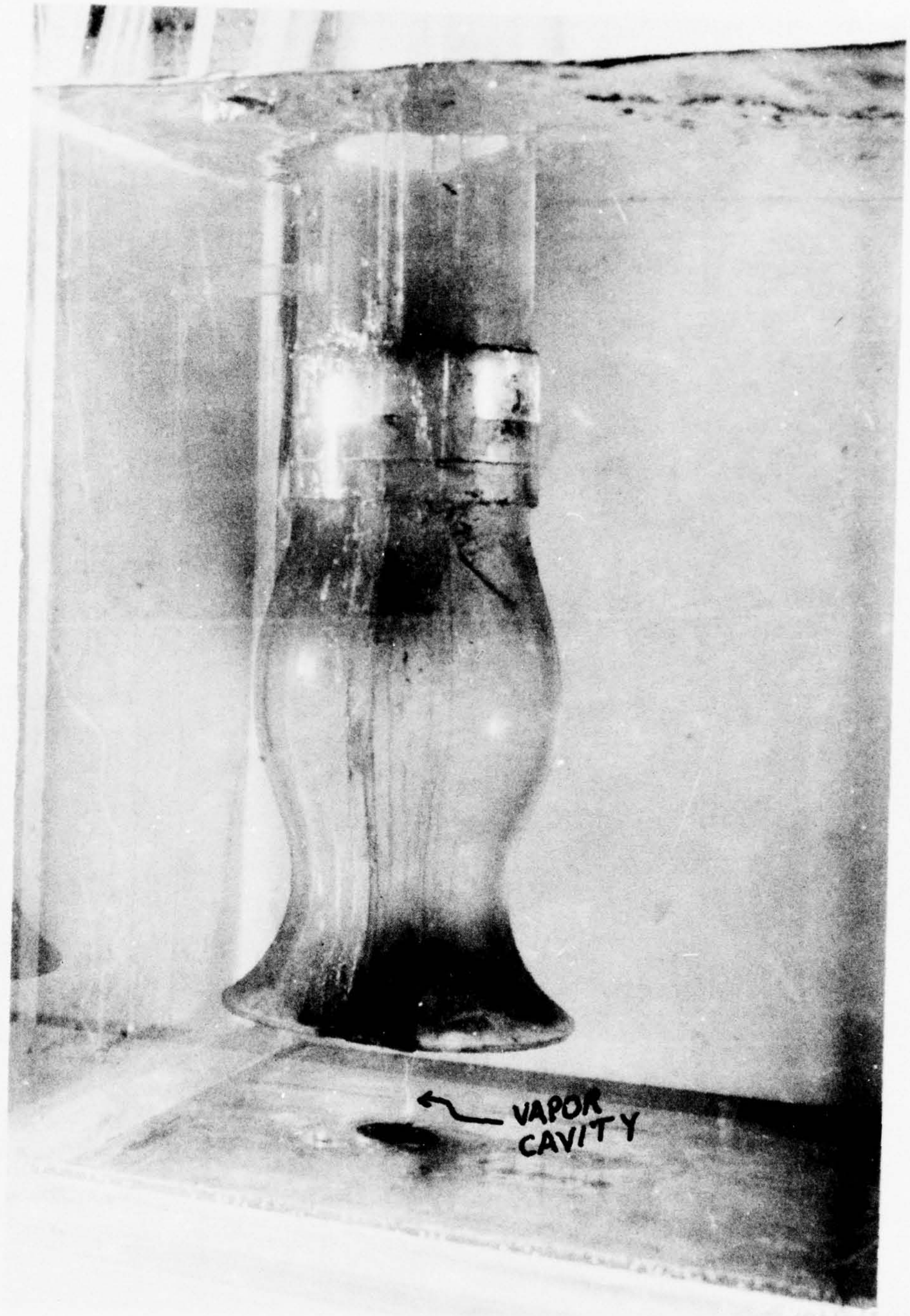


Photo 7. Flow conditions; original design sump, all pumps discharging (discharge, 13 cfs per pump), sump el 299.0. Note vapor cavity below intake

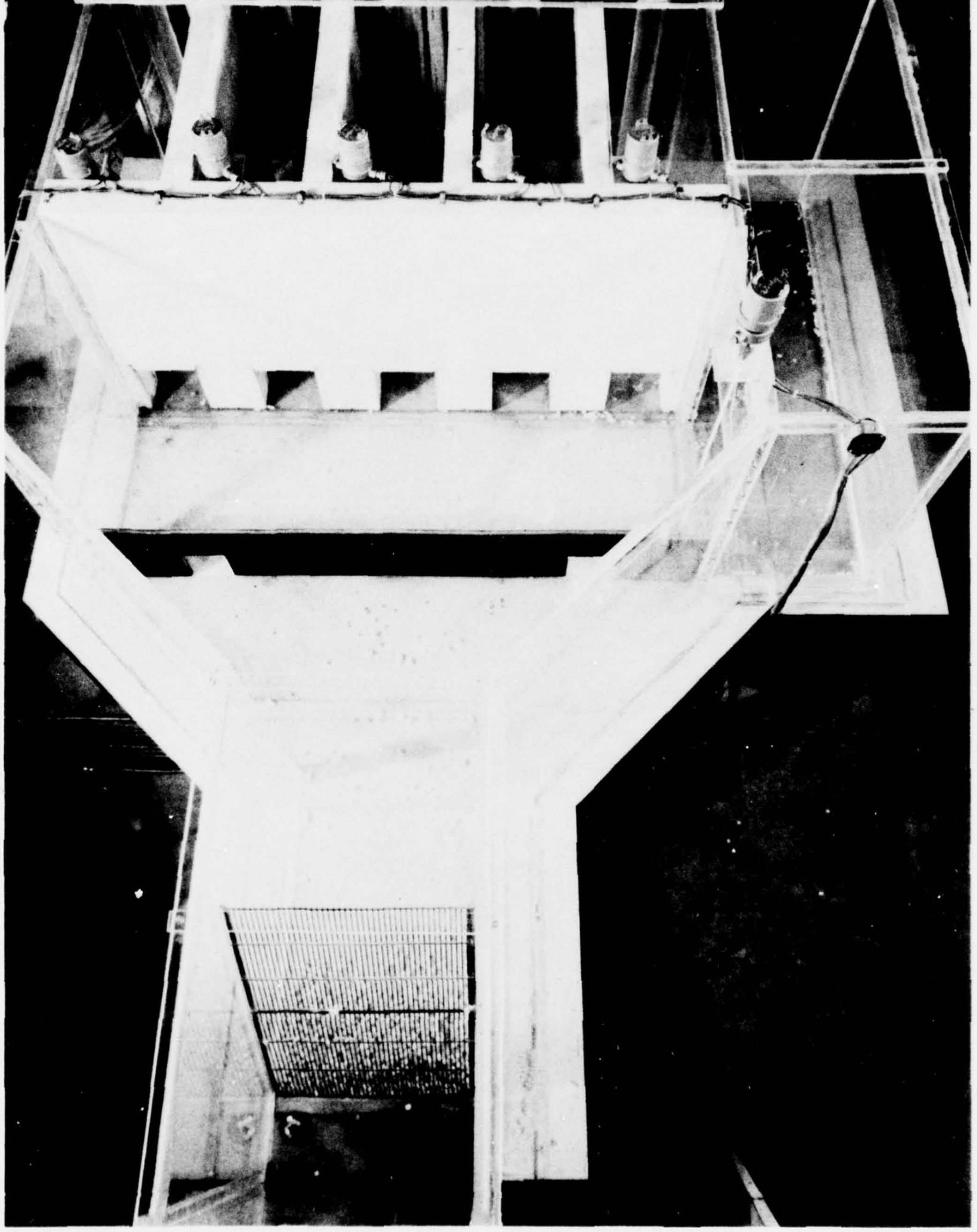


Photo 8. Type 1 baffle

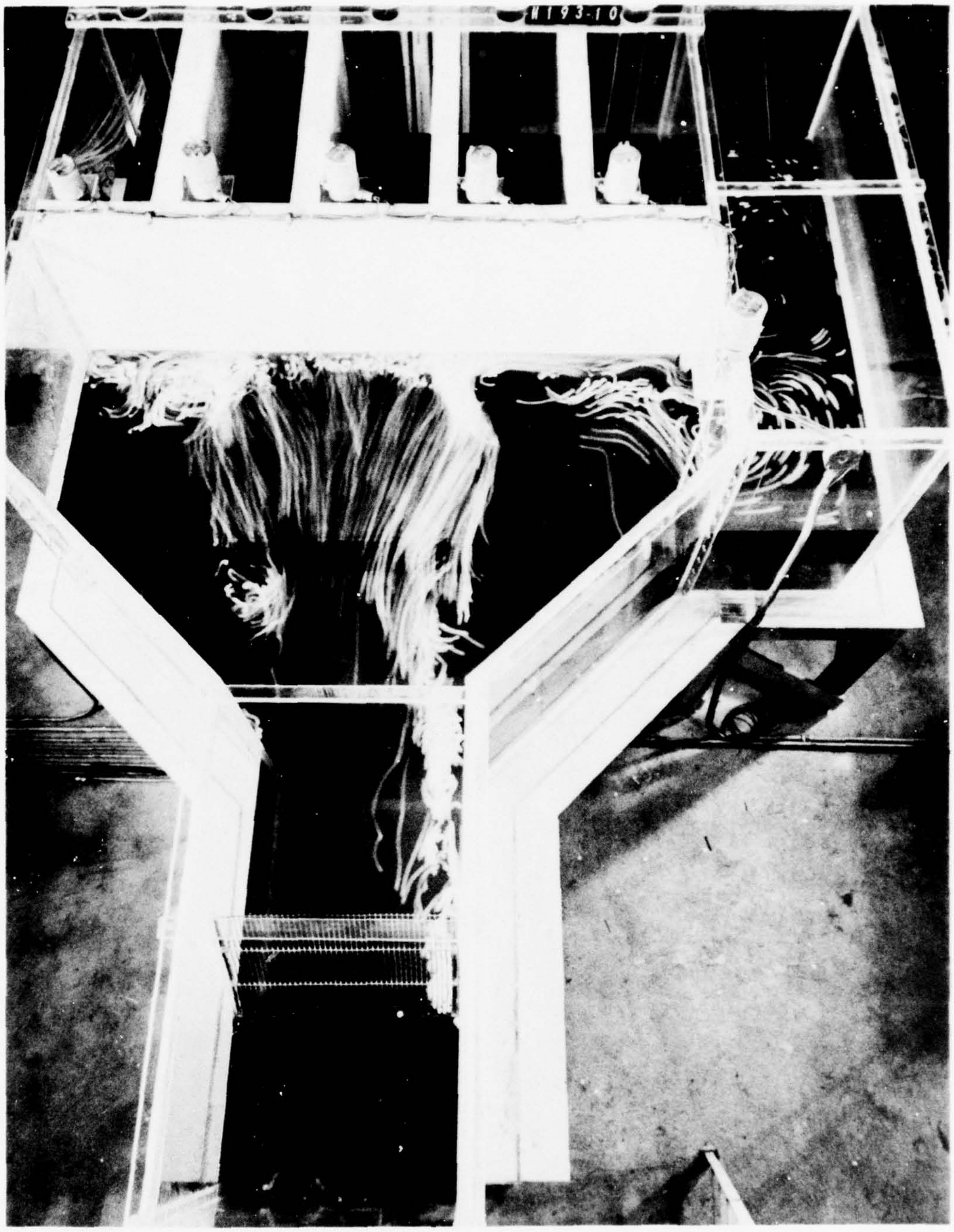


Photo 9. Flow conditions; type 1 baffle, all pumps operating, sump el 299.0

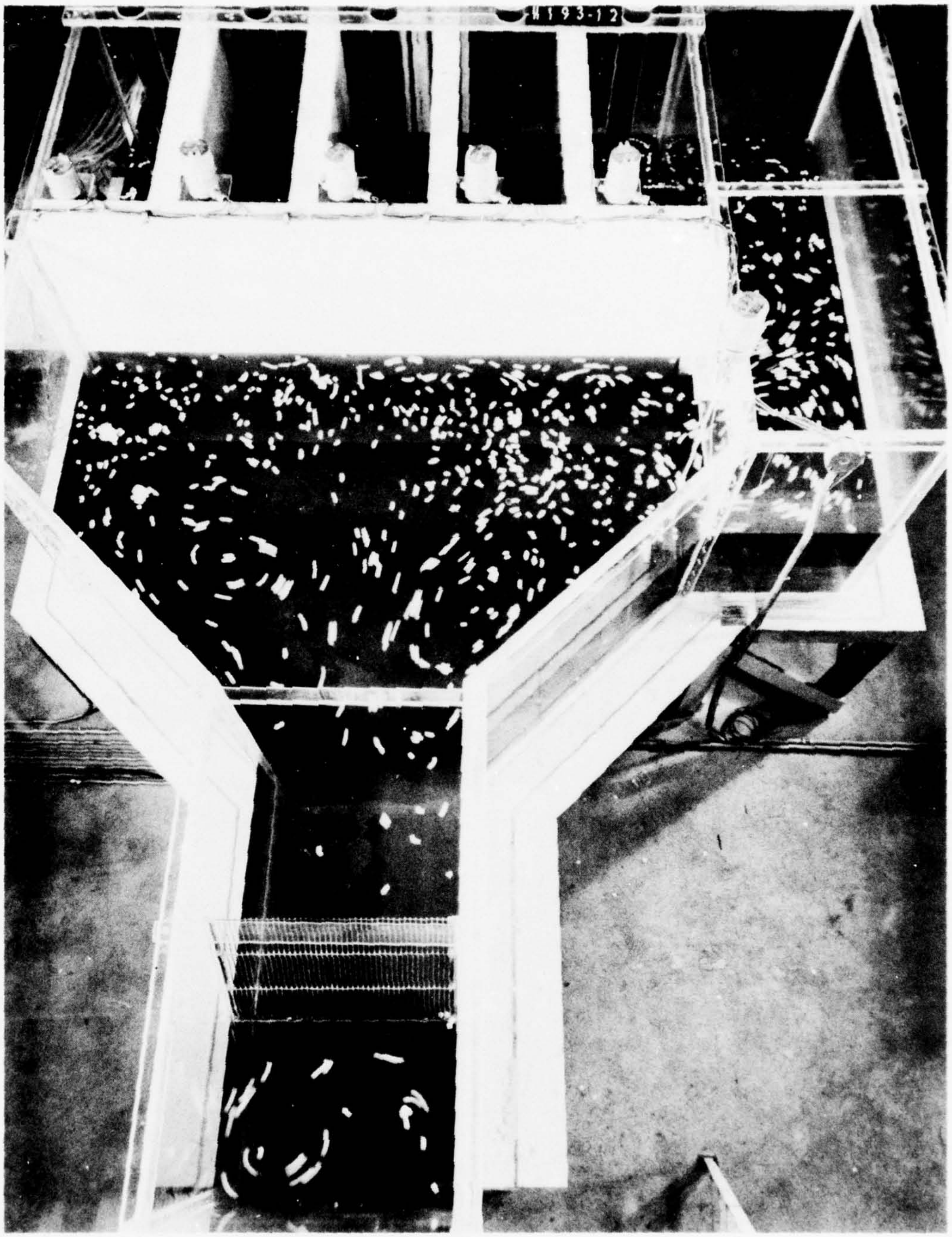


Photo 10. Flow conditions; type 1 baffle, pump 2 operating, sump el 299.0

Photo 11. Flow conditions; type 1 baffle, pump 3 operating, sump el 299.0

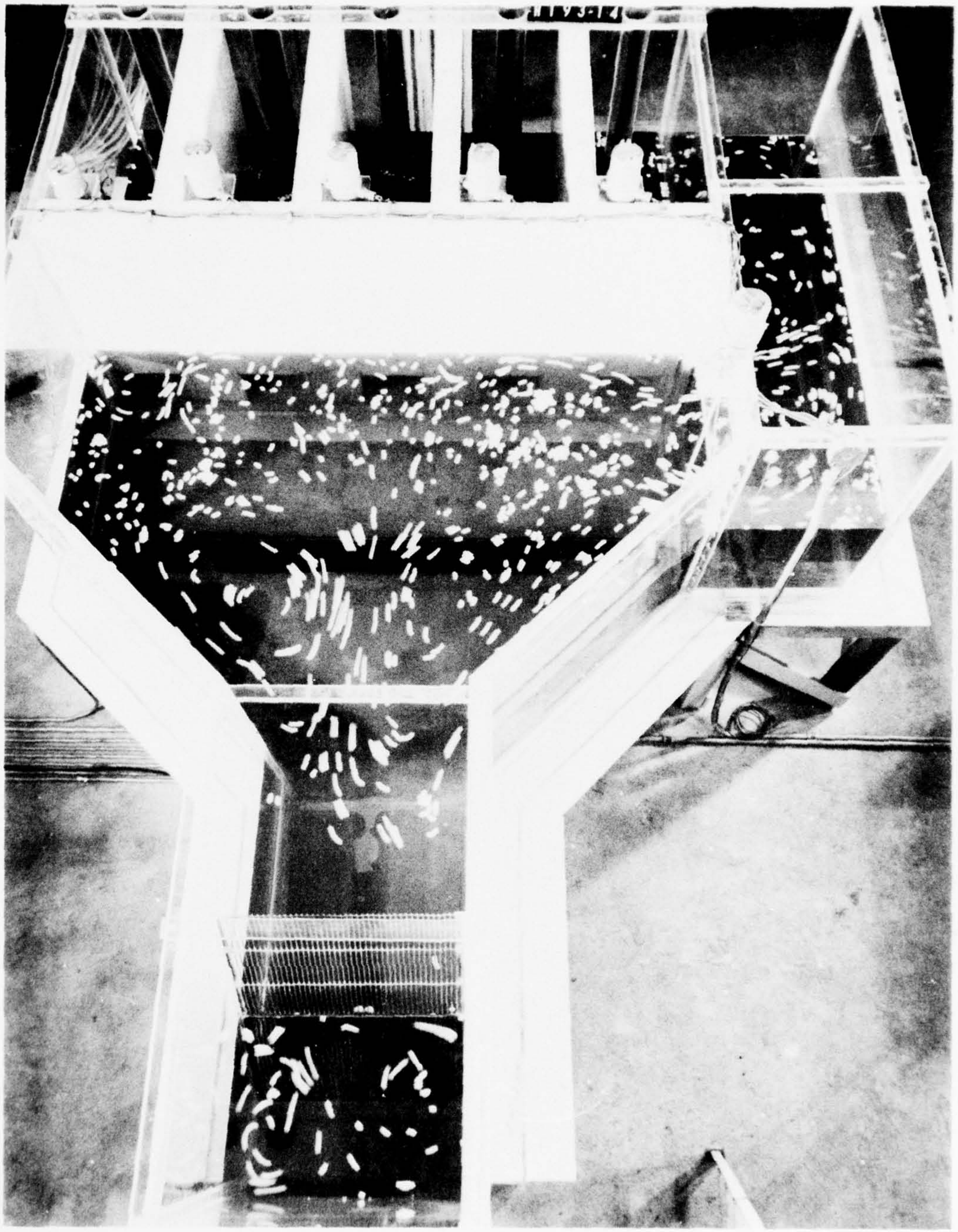


Photo 12. Flow conditions; type 1 baffle, pump 4 operating, sump el 299.0

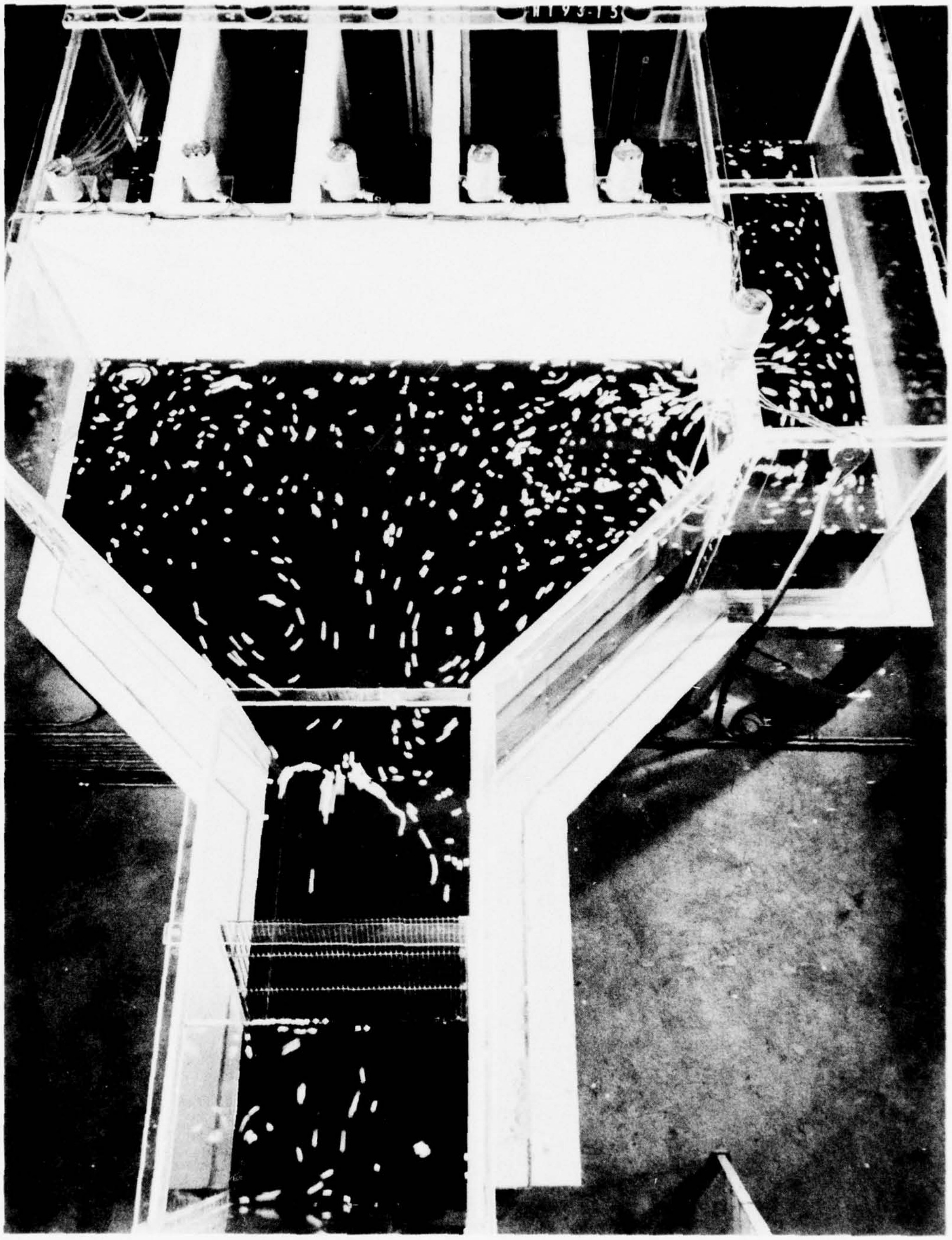


Photo 13. Flow conditions; type 1 baffle, pump 5 operating, sump el 299.0

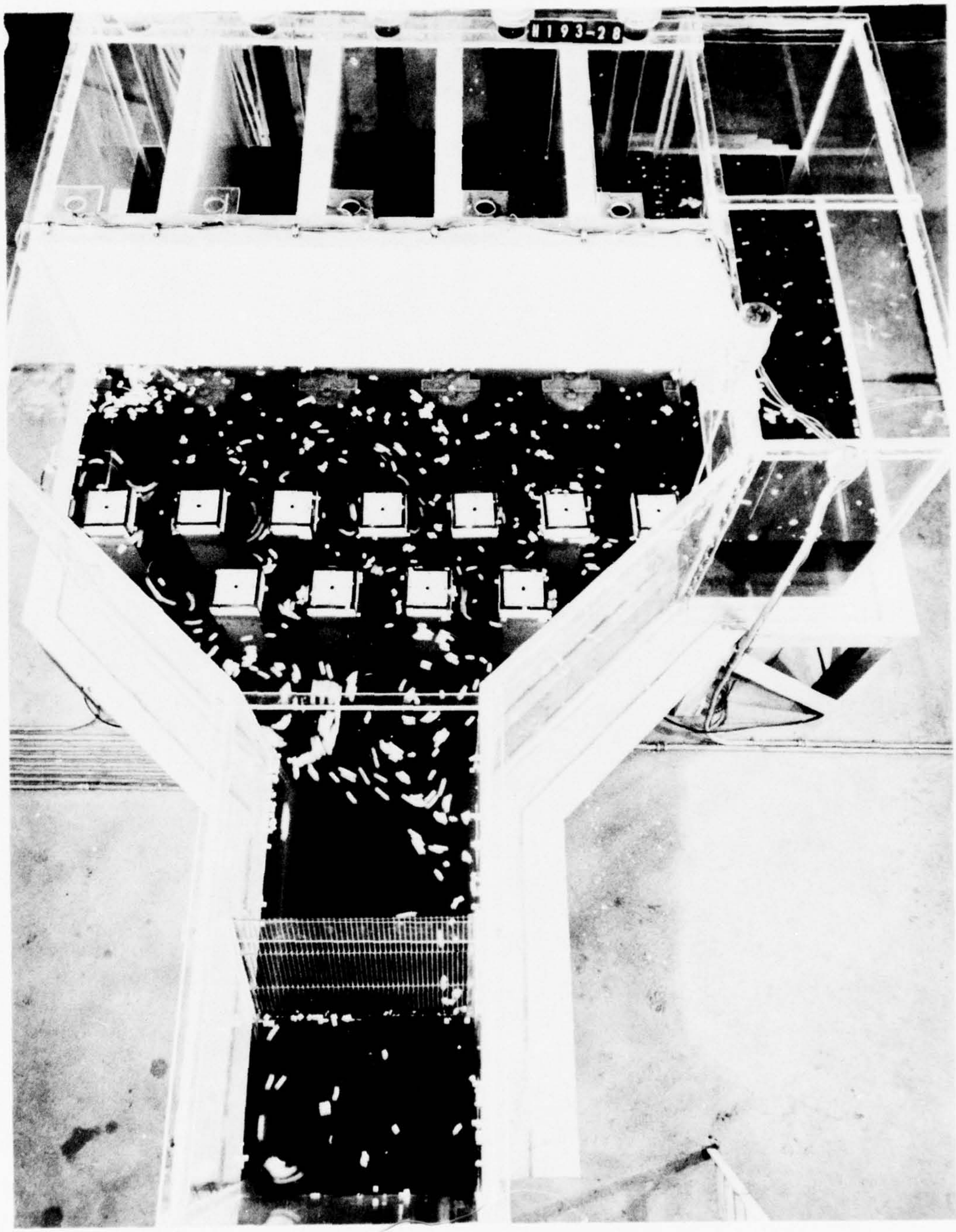


Photo 14. Flow conditions; recommended design, pump 1 operating, sump el 299.0

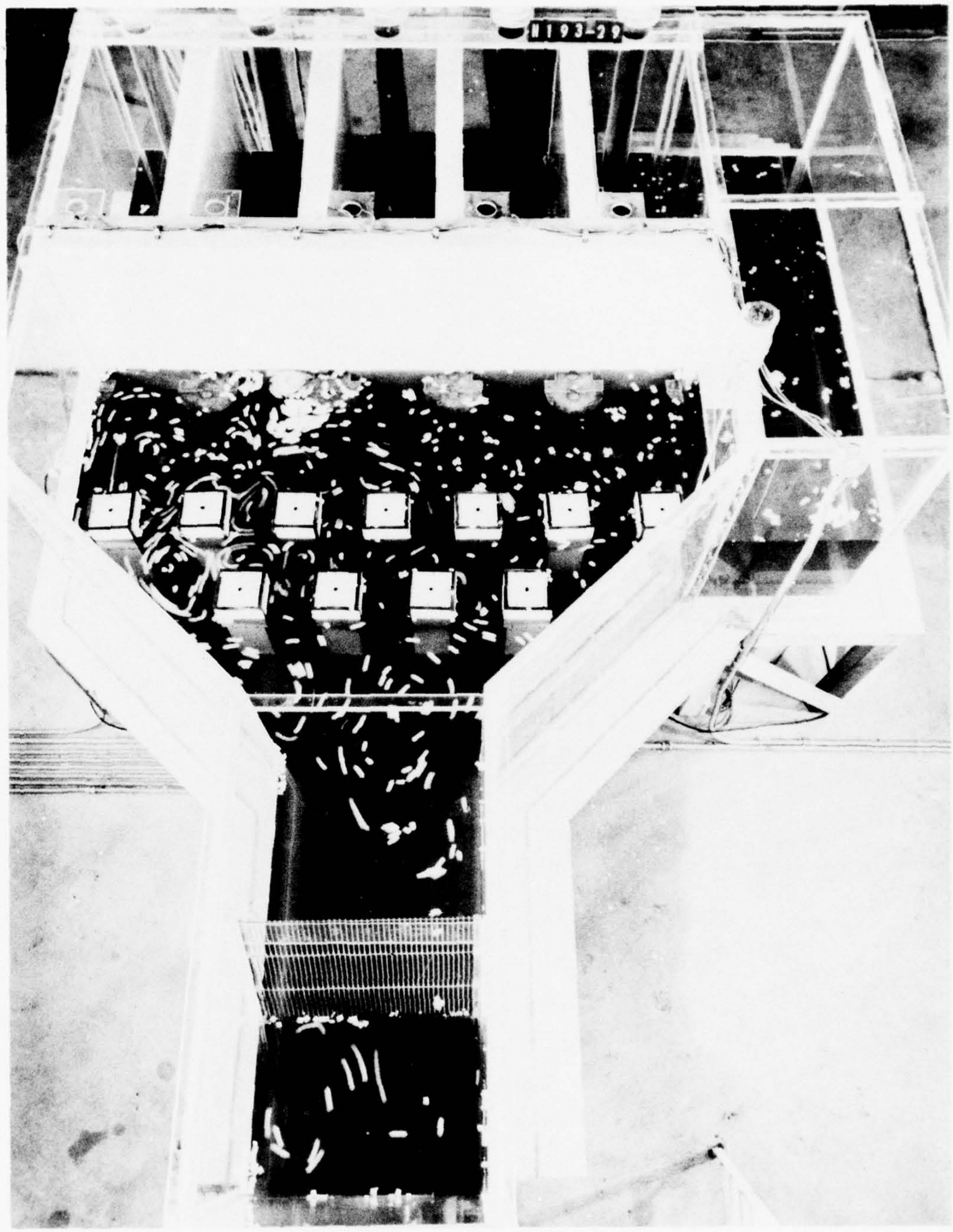


Photo 15. Flow conditions; recommended design, pump 2 operating, sump el 299.0

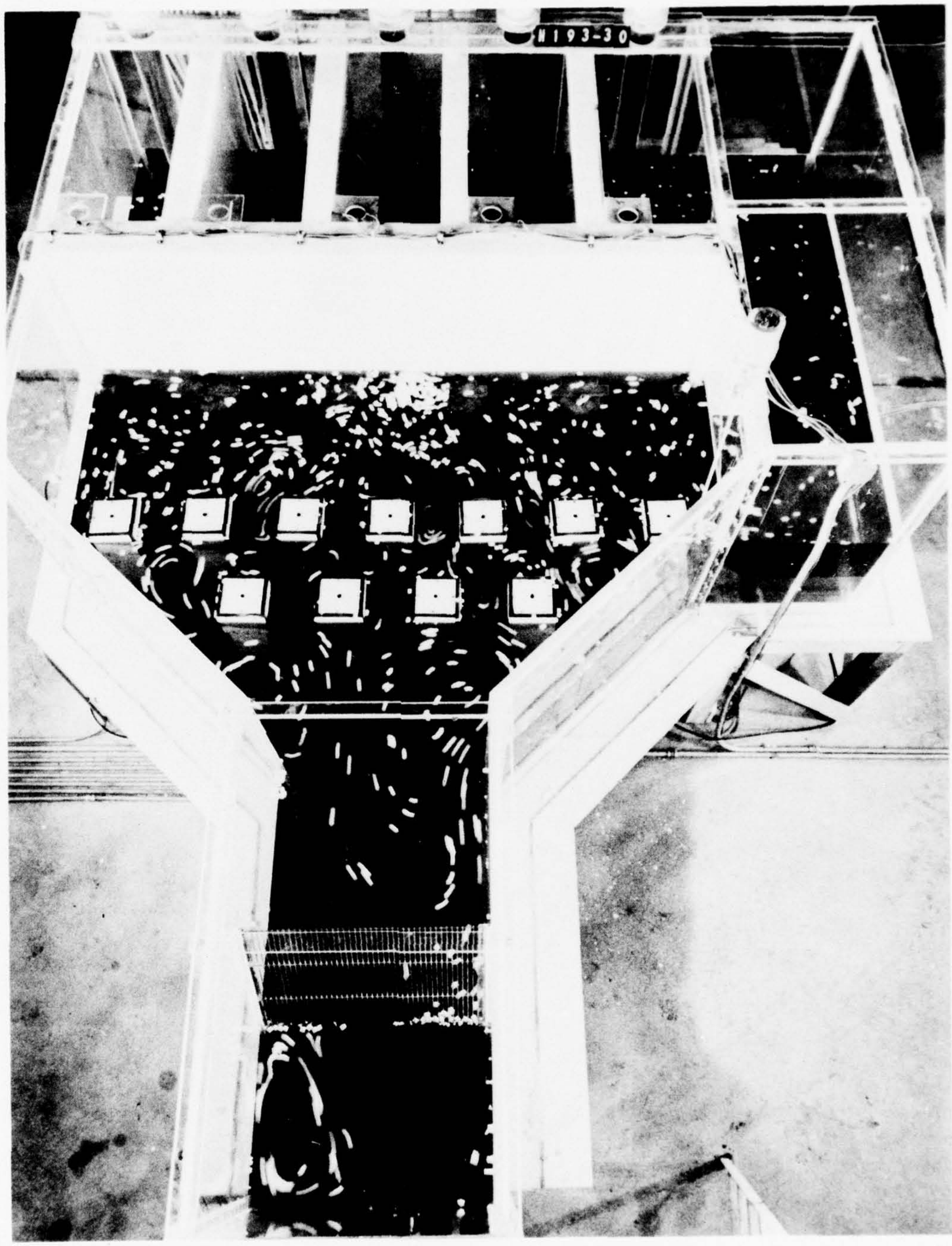


Photo 16. Flow conditions; recommended design, pump 3 operating, sump el 299.0

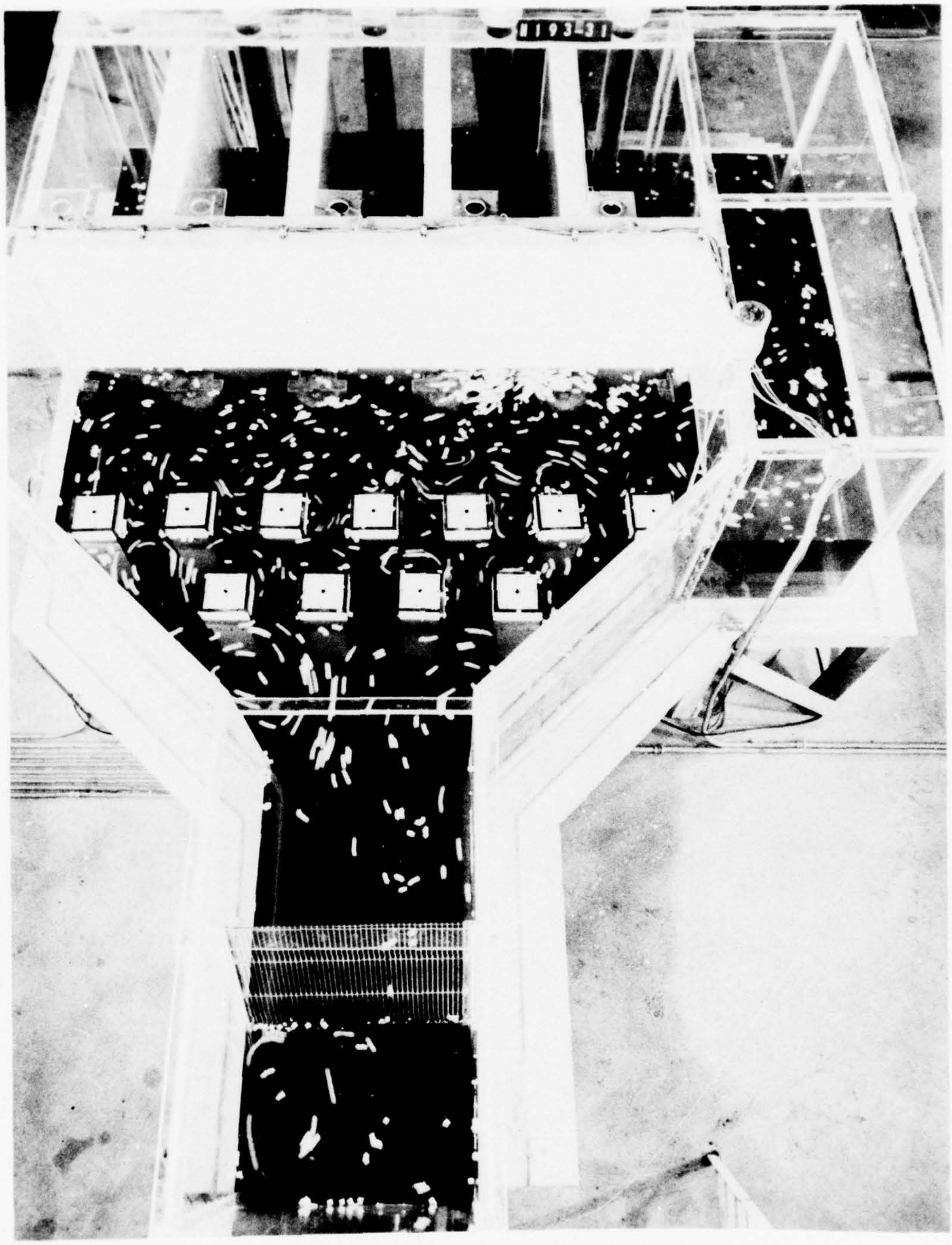


Photo 17. Flow conditions; recommended design, pump 4 operating, sump el 299.0

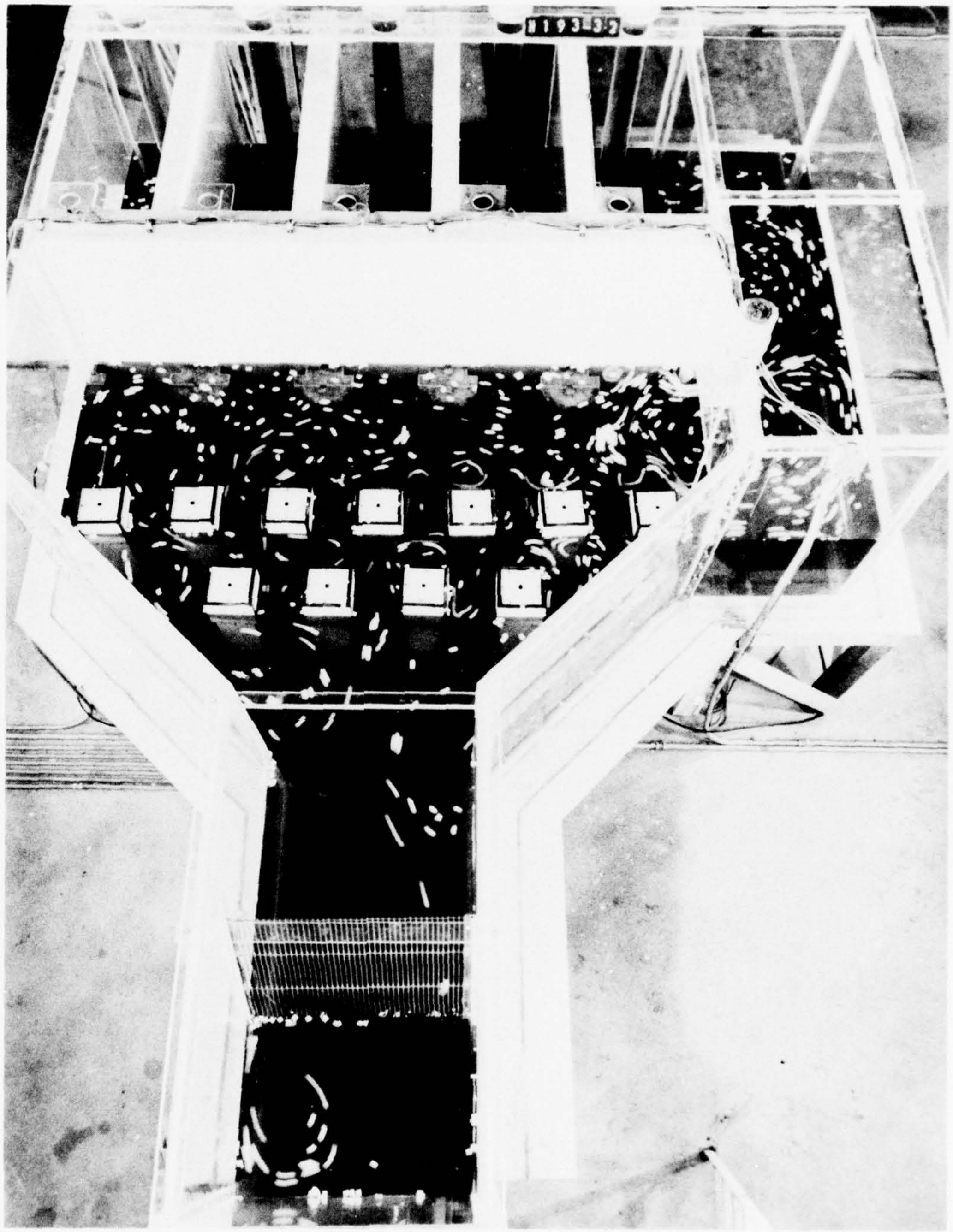


Photo 18. Flow conditions; recommended design, pump 5 operating, sump el 299.0

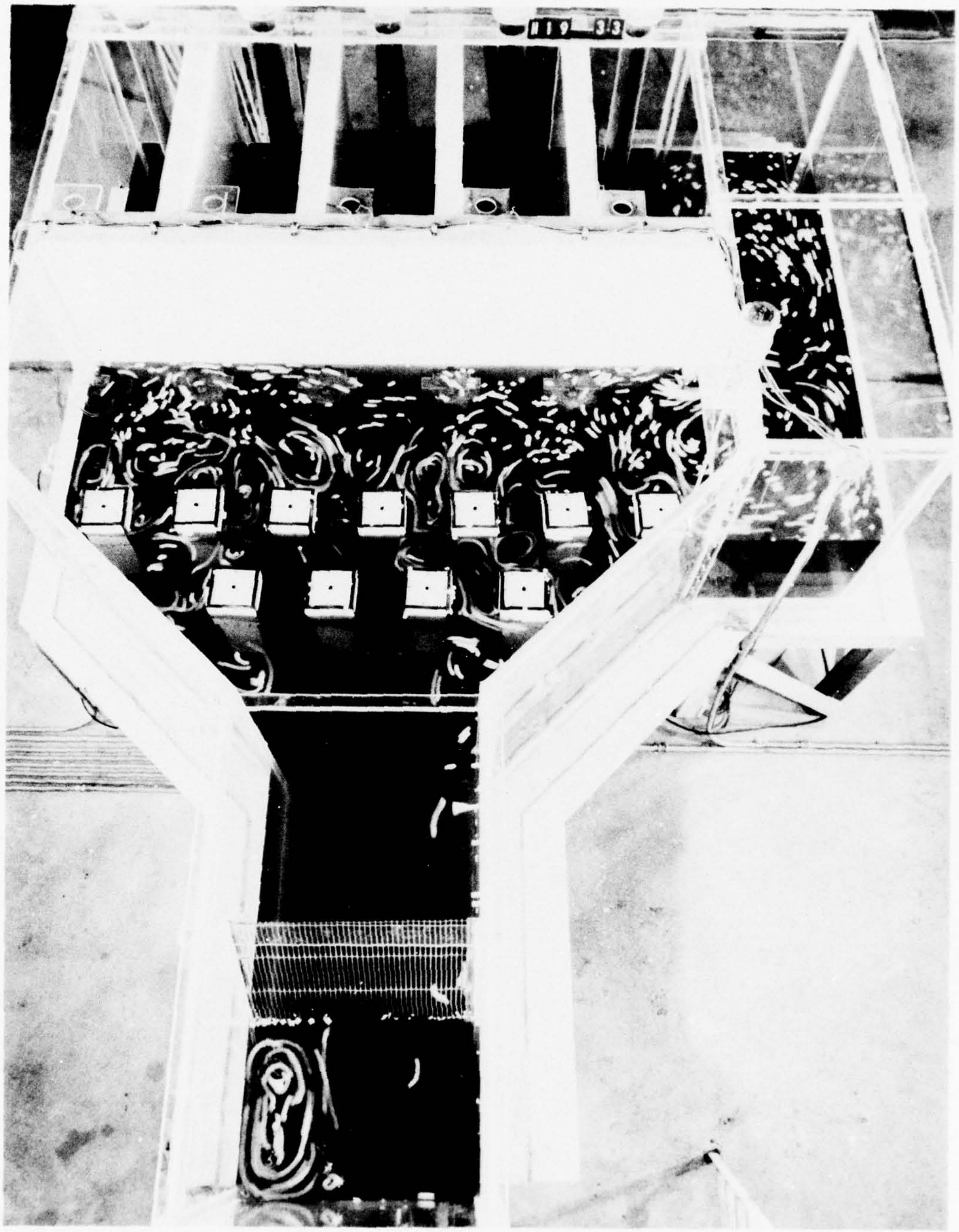


Photo 19. Flow conditions; recommended design, pumps 1 and 5 operating, sump el 299.0

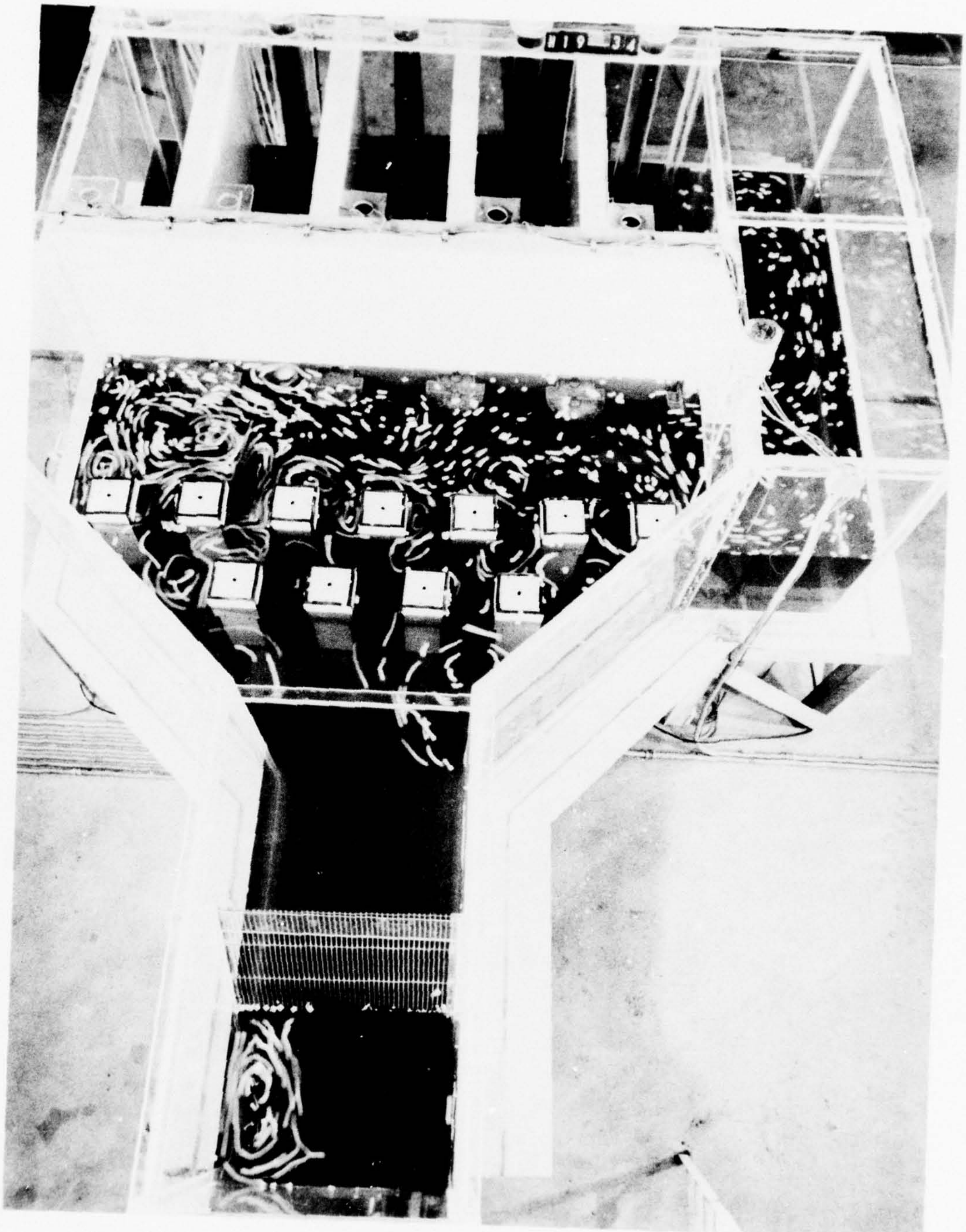


Photo 20. Flow conditions; recommended design, pumps 1 and 2 operating, sump el 299.0

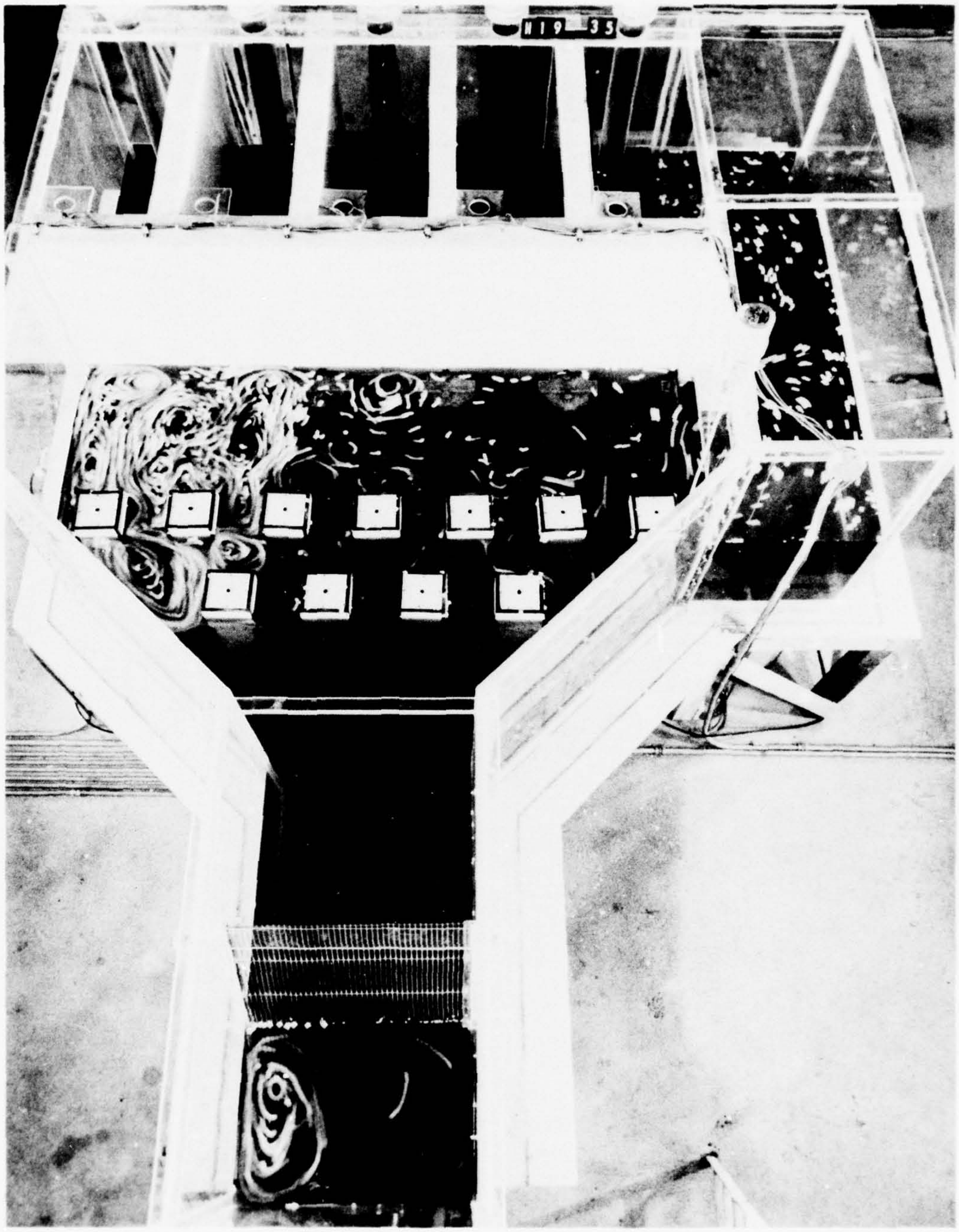


Photo 21. Flow conditions; recommended design, pumps 1-3 operating, sump el 299.0

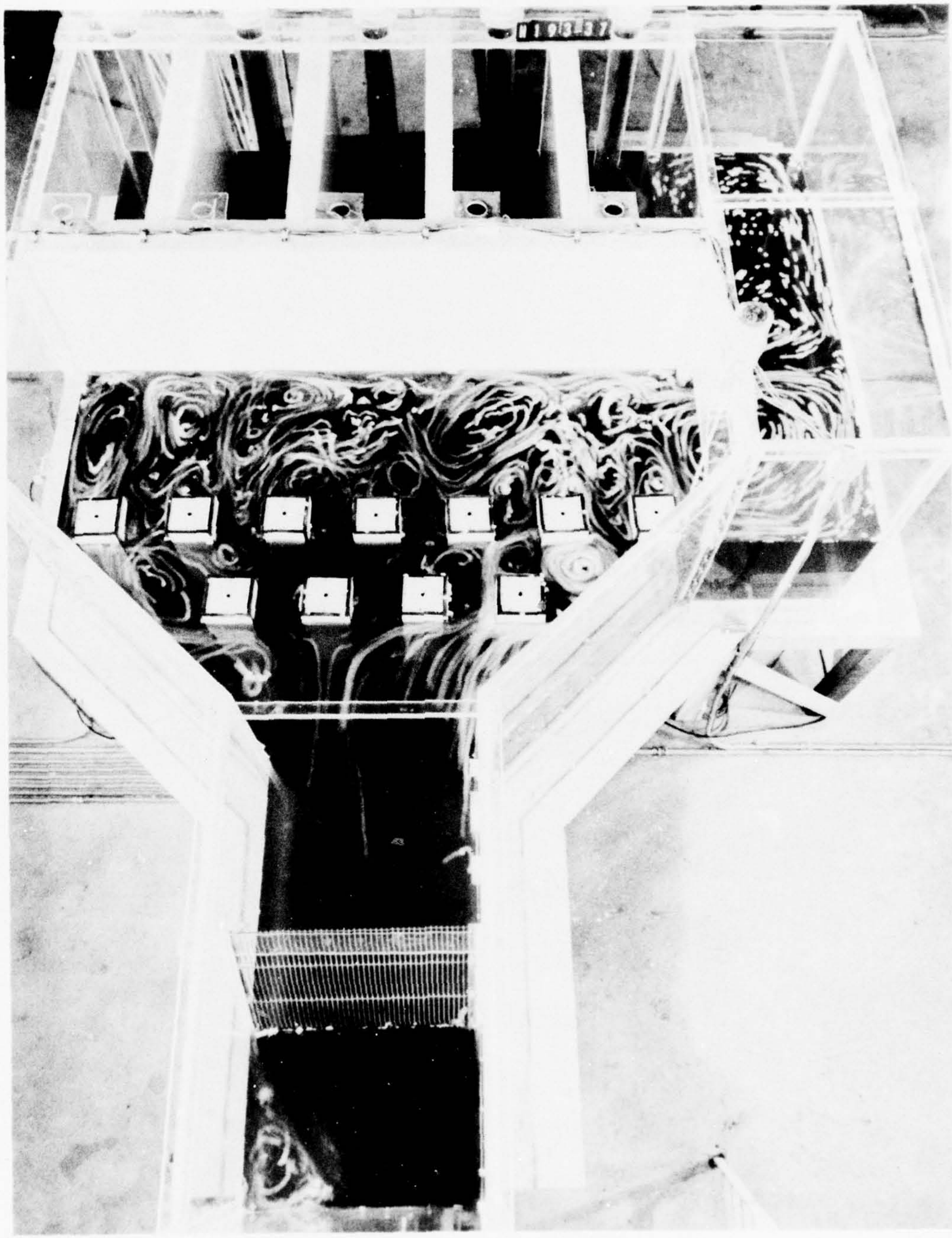


Photo 22. Flow conditions recommended design, pumps 1-5 operating, sump el 299.0

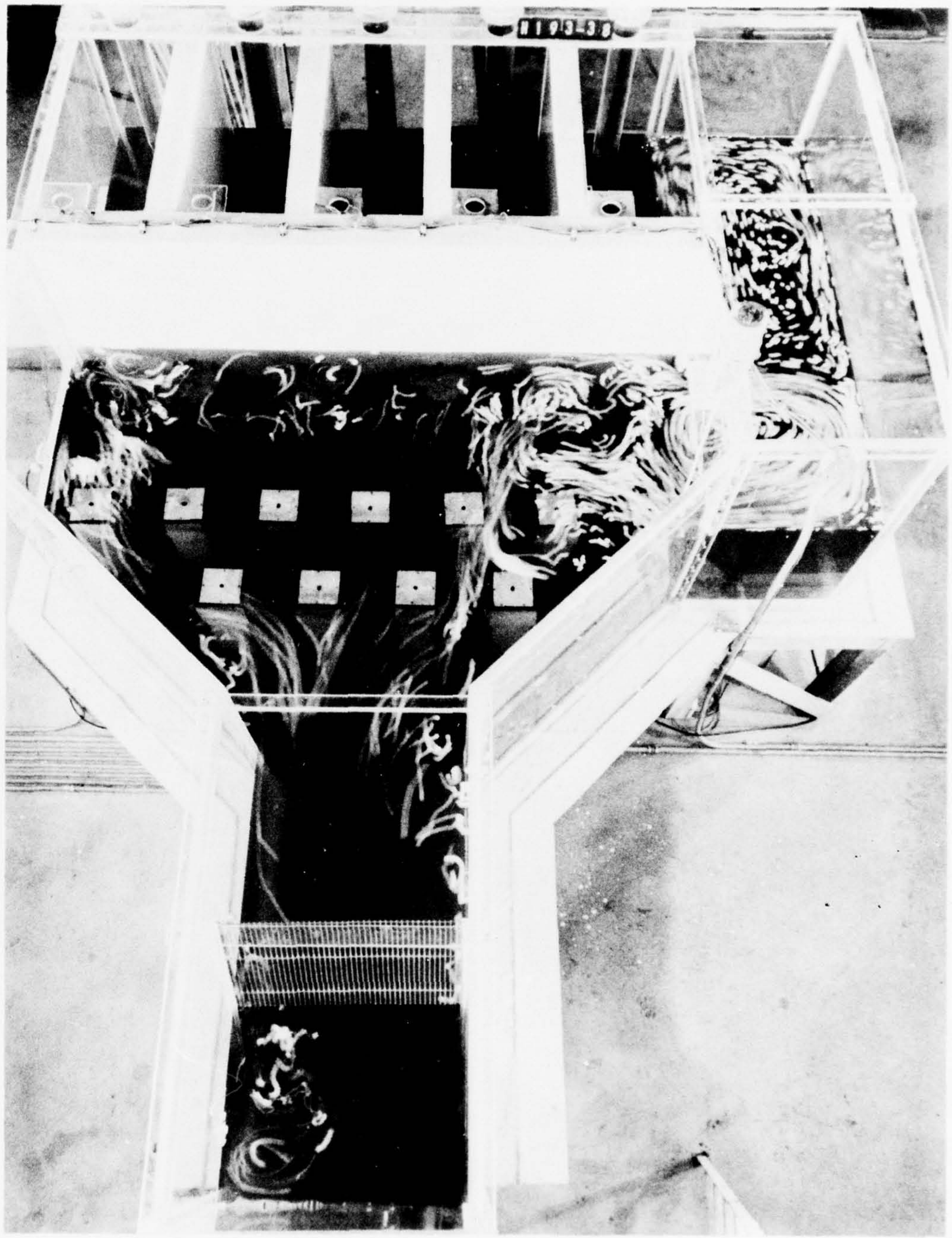


Photo 23. Flow conditions; recommended design, pumps 1-5 operating, sump el 300.0

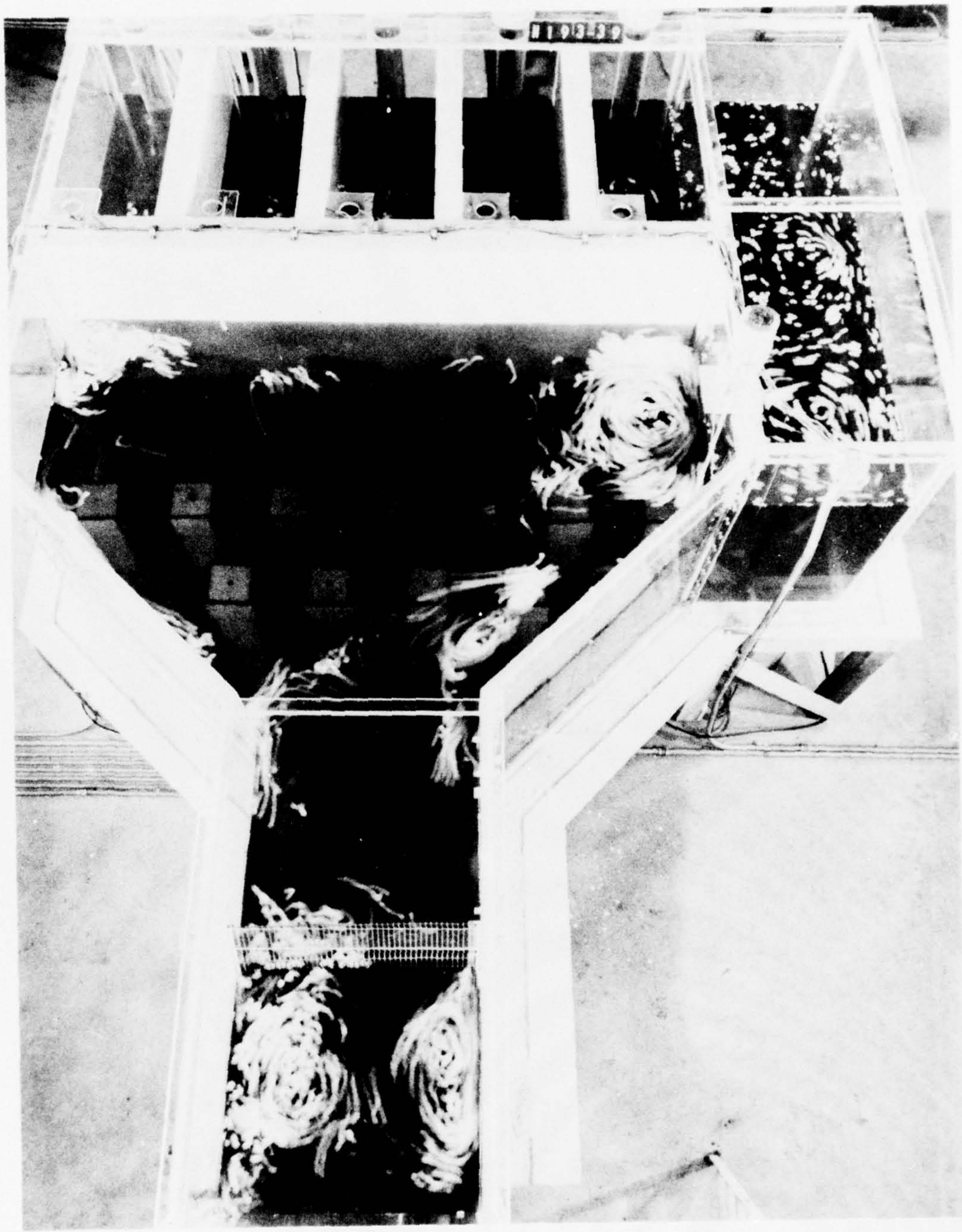


Photo 24. Flow conditions; recommended design, pumps 1-5 operating, sump el 302.0

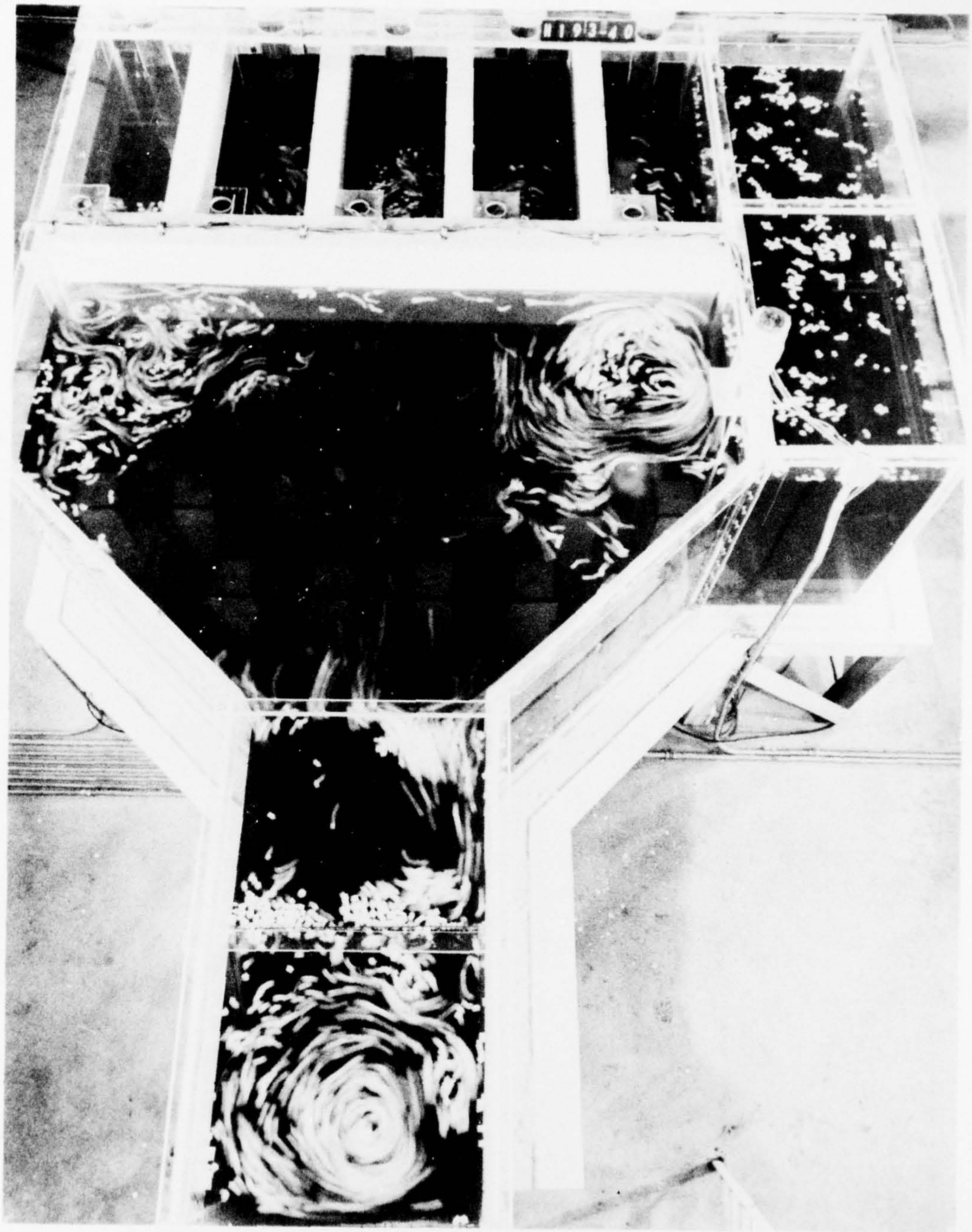
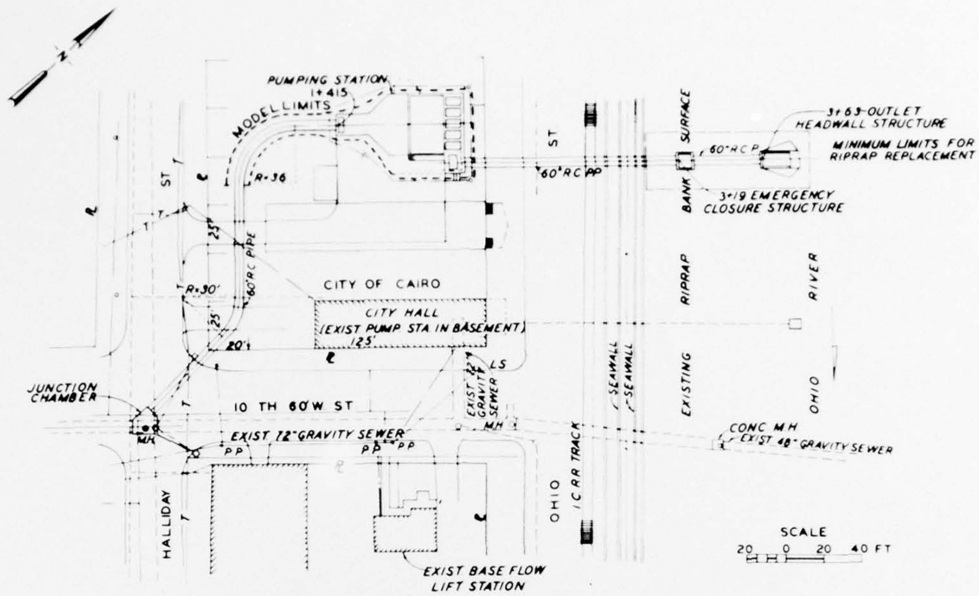
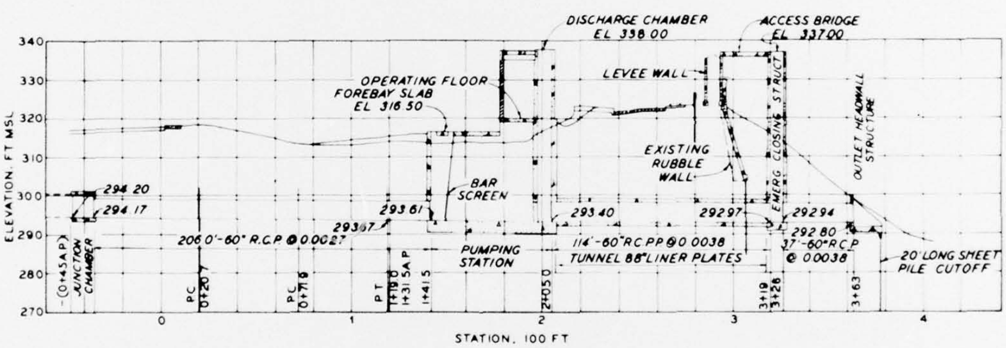


Photo 25. Flow conditions; recommended design, pumps 1-5 operating, sump el 304.0

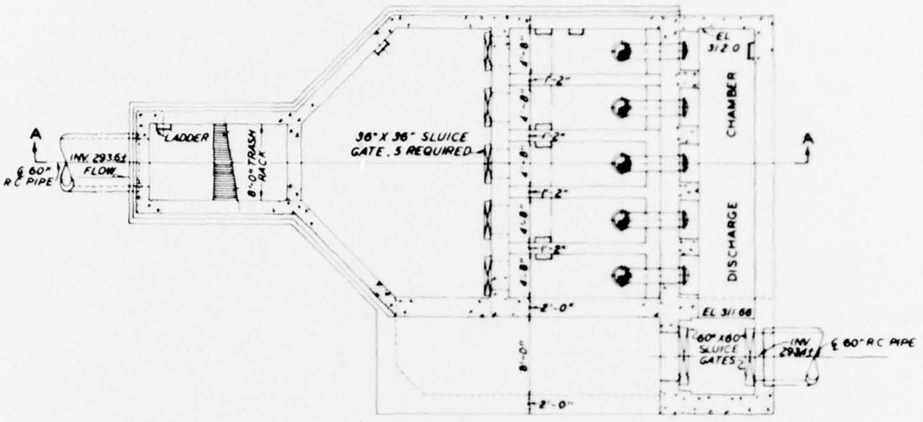


LOCATION AND MODEL LIMITS

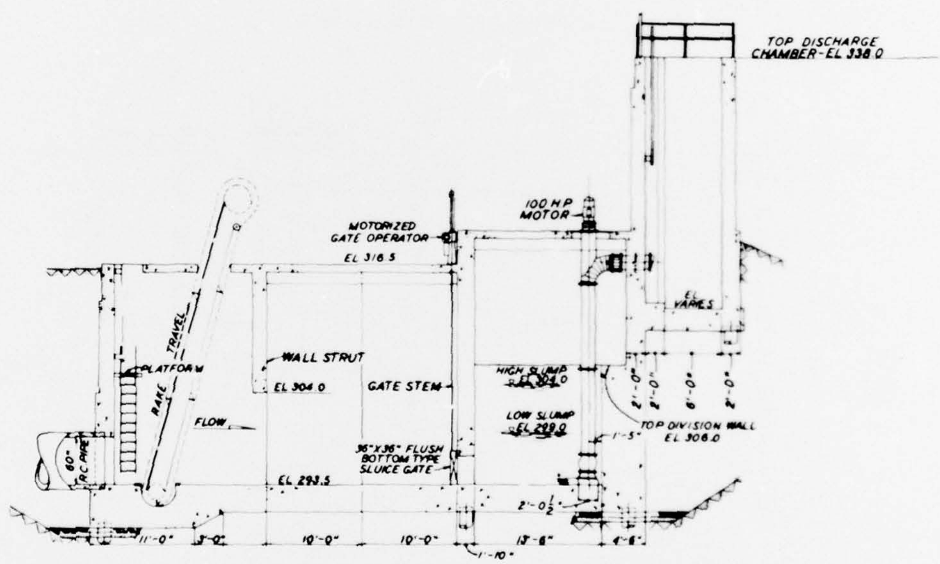


PROFILE

LOCATION AND PROFILE OF
10TH STREET PUMPING STATION



PLAN



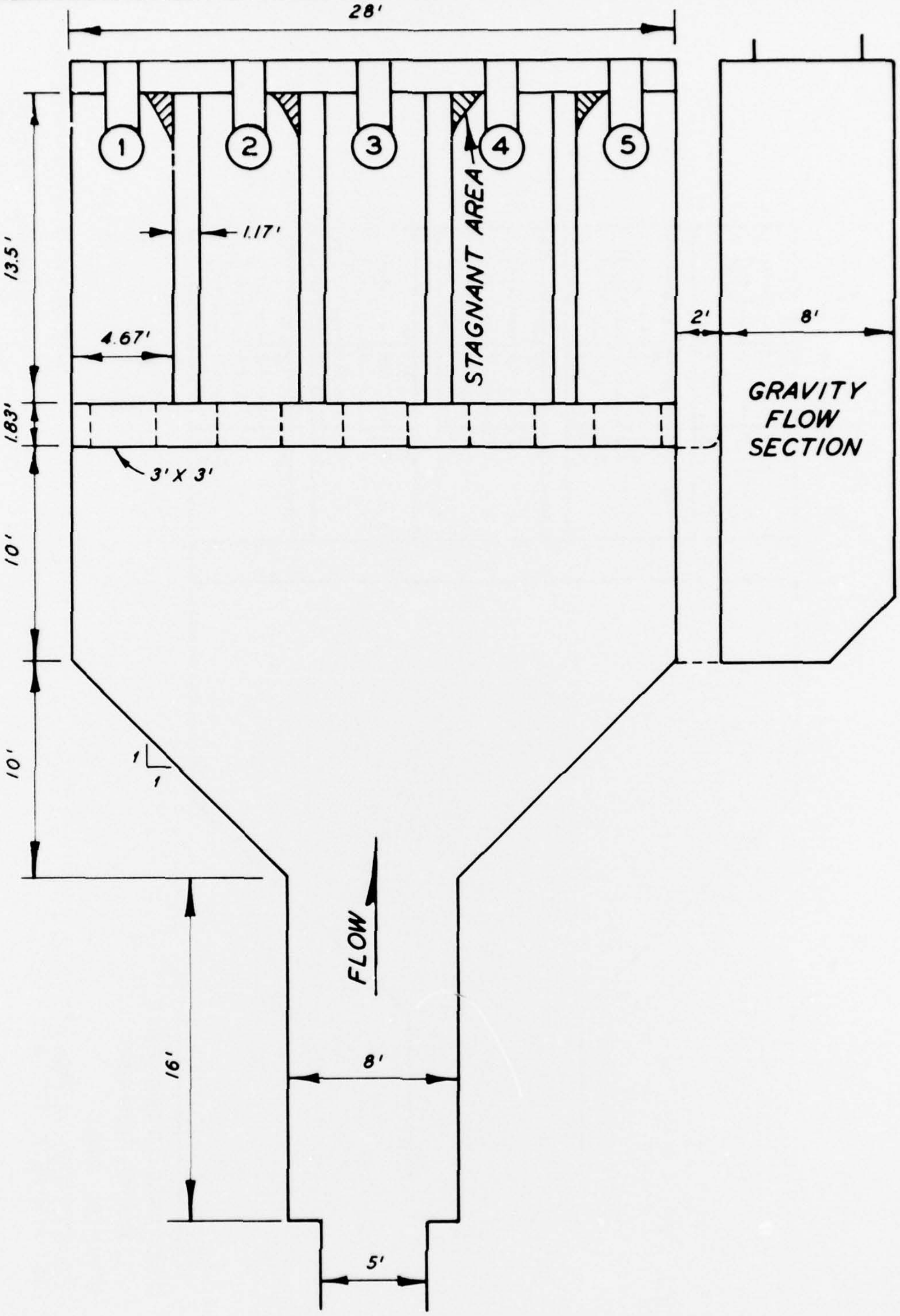
SECTION A–A

SCALE

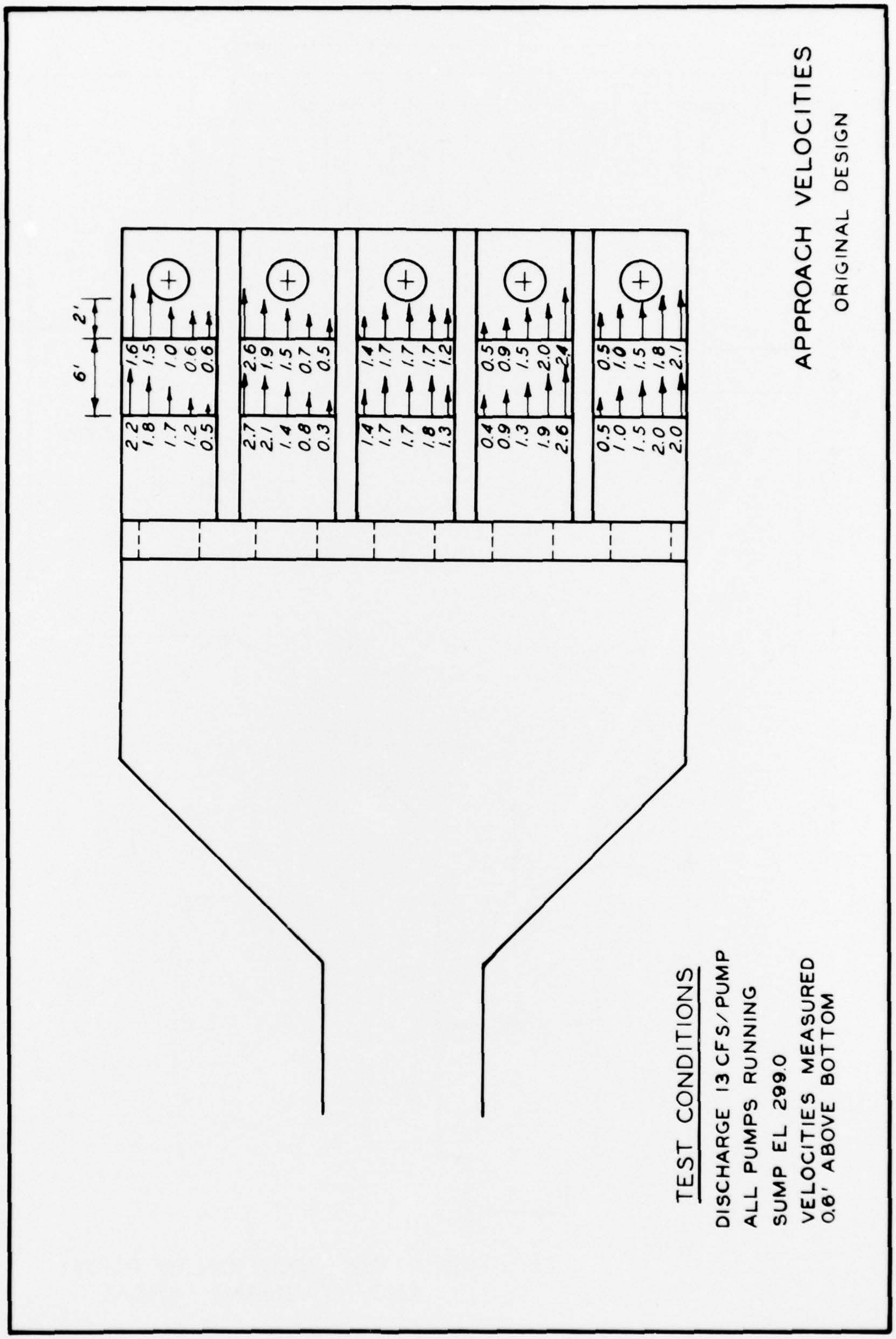
2 0 2 4 6 8 FT

PLAN AND DETAILS OF
10TH STREET PUMPING STATION

PLATE 2

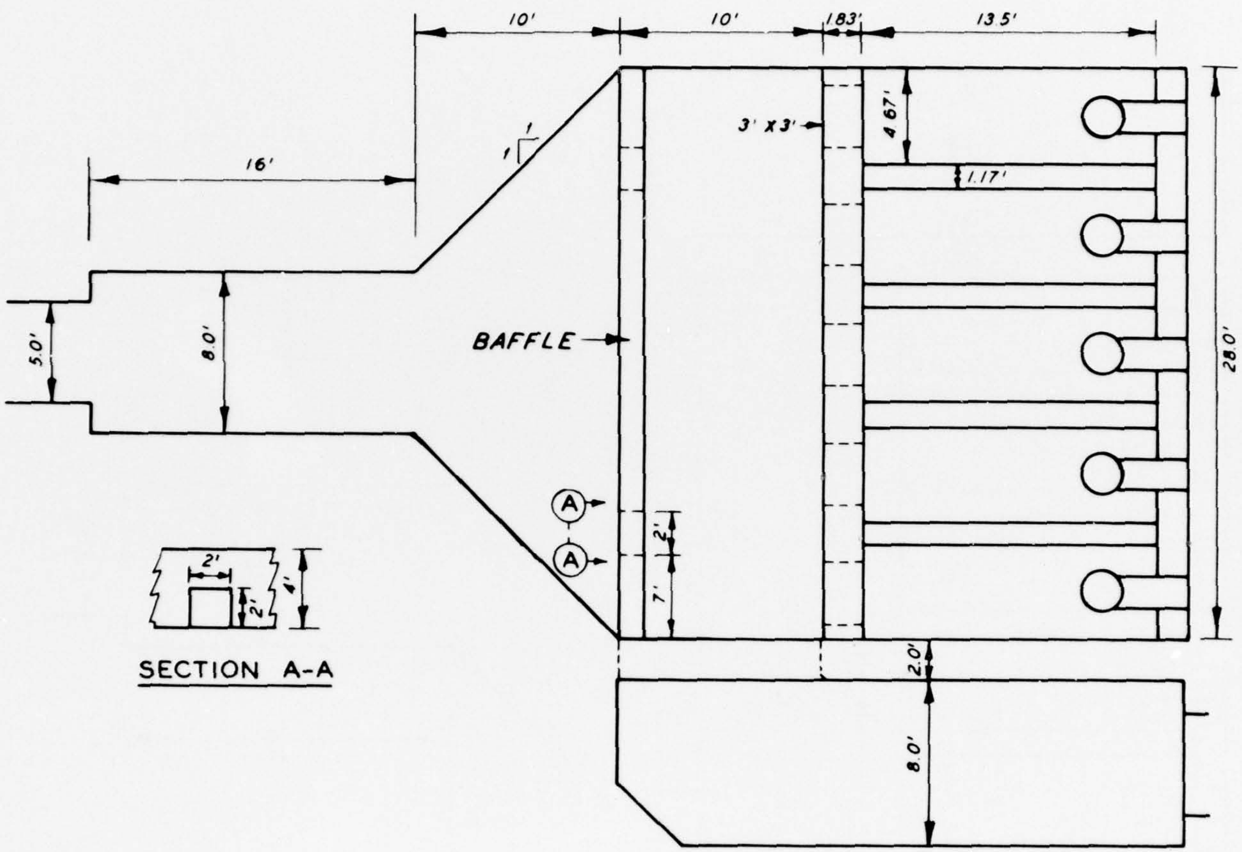


RELATIVE POSITION OF PUMPS AND STAGNANT AREAS



APPROACH VELOCITIES
ORIGINAL DESIGN
TEST CONDITIONS
DISCHARGE 13 CFS/PUMP
ALL PUMPS RUNNING
SUMP EL 299.0
VELOCITIES MEASURED
0.6' ABOVE BOTTOM
6'
2'
2.2 1.8 1.7 1.2 0.5
1.6 1.5 1.0 0.6 0.6
2.7 2.1 1.4 0.8 0.3
2.6 1.9 1.5 0.7 0.5
1.4 1.7 1.7 1.8 1.3
1.4 1.7 1.7 1.7 1.2
0.4 0.9 1.3 1.9 2.6
0.5 0.9 1.5 2.0 2.4
0.5 1.0 1.5 2.0 2.0
0.5 1.0 1.5 1.8 2.1

PLATE 4



TYPE 1 BAFFLE

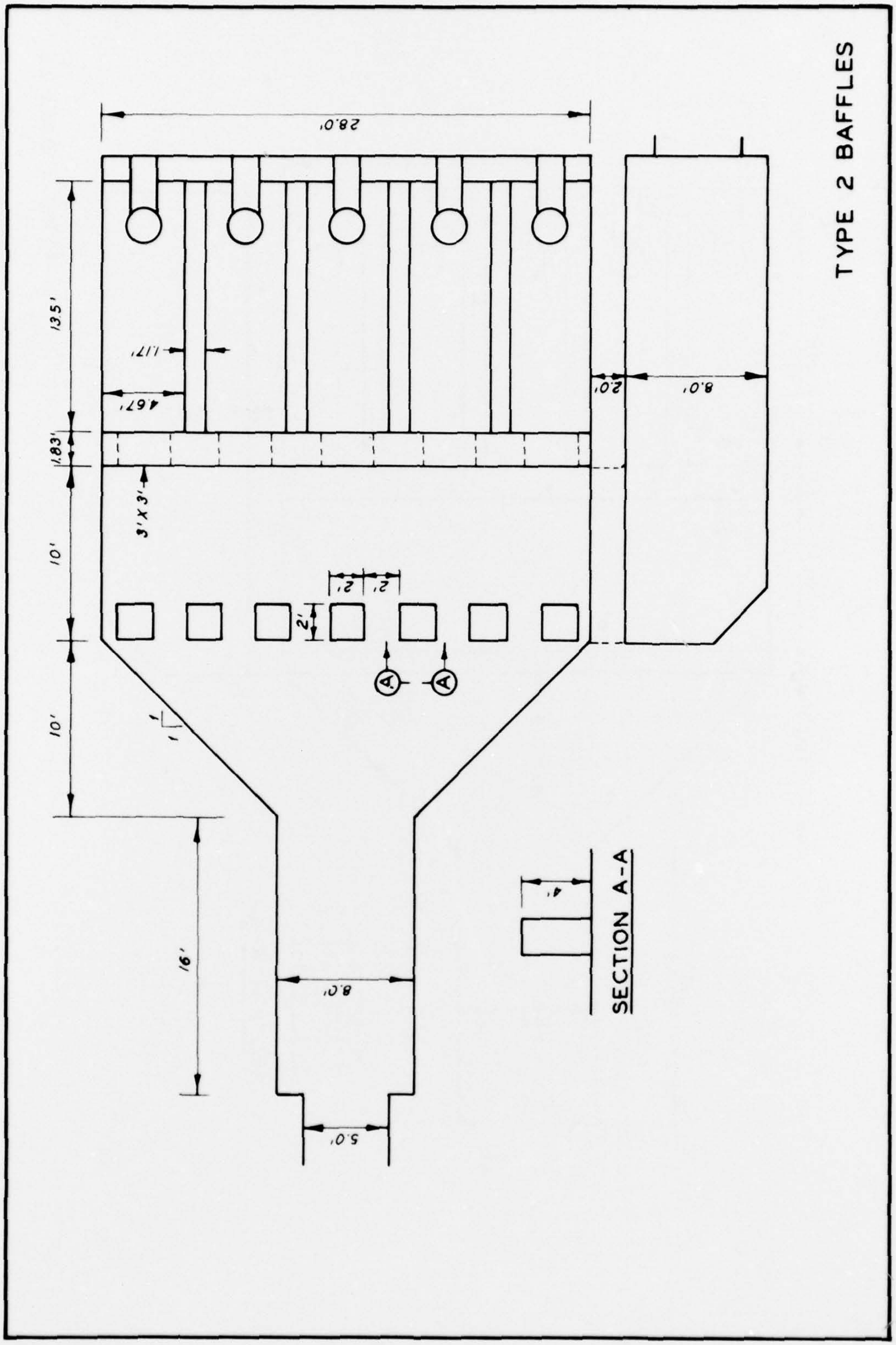
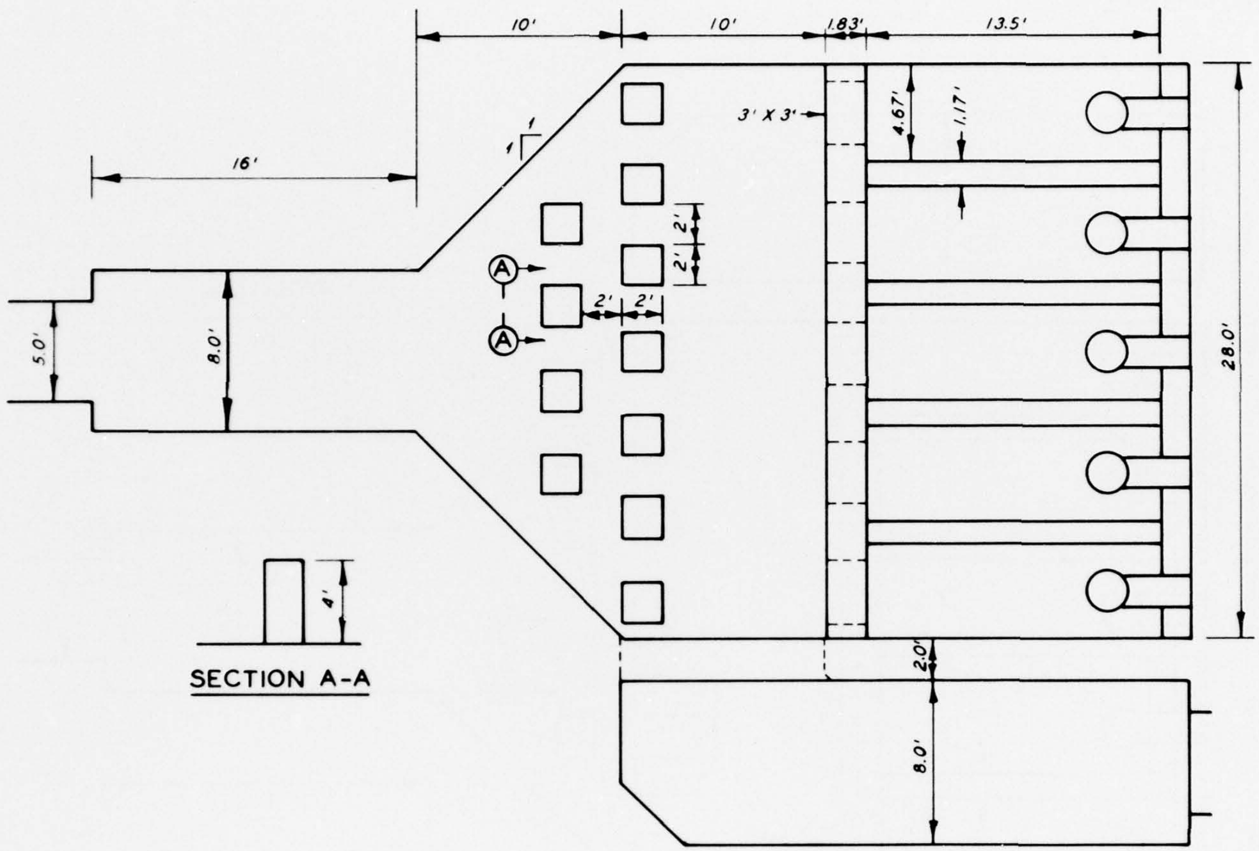

TYPE 2 BAFFLES
28.0'
13.5'
1.17'
4.67'
2.0'
8.0'
1.83'
3' X 3'
10'
2'
2'
2'
A
A
10'
1
1
16'
8.0'
5.0'
4'
SECTION A-A

PLATE 6



TYPE 3 BAFFLES

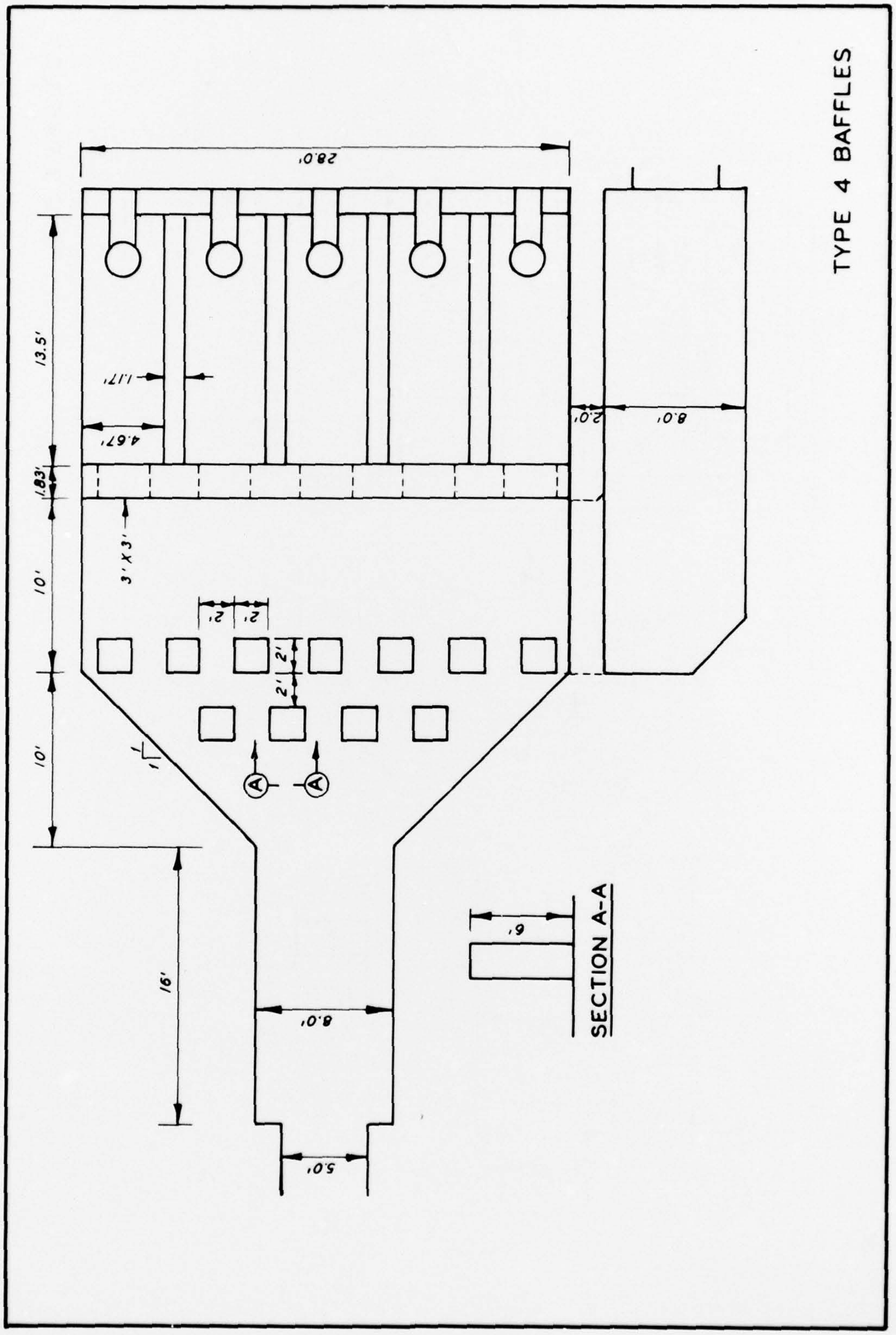
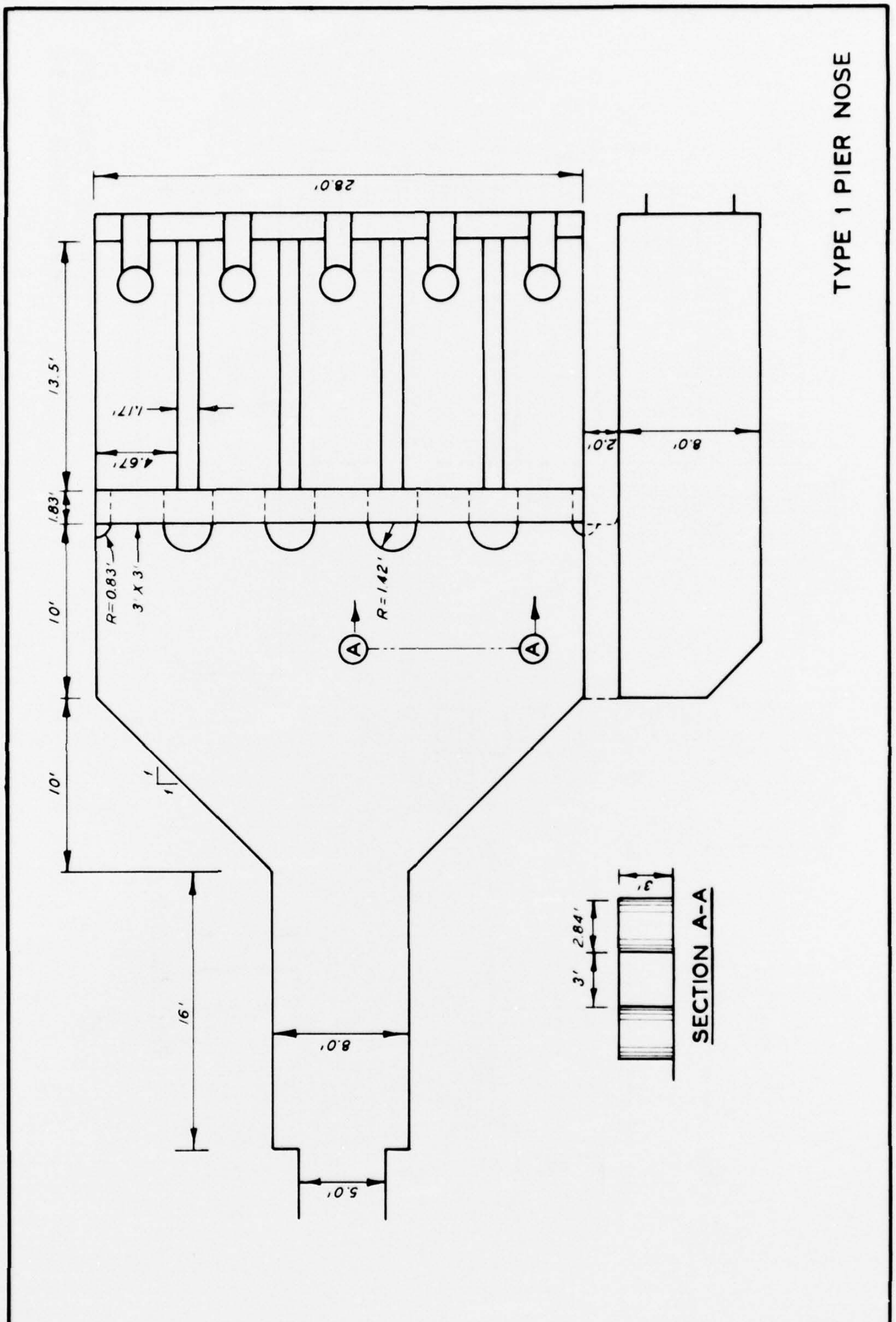
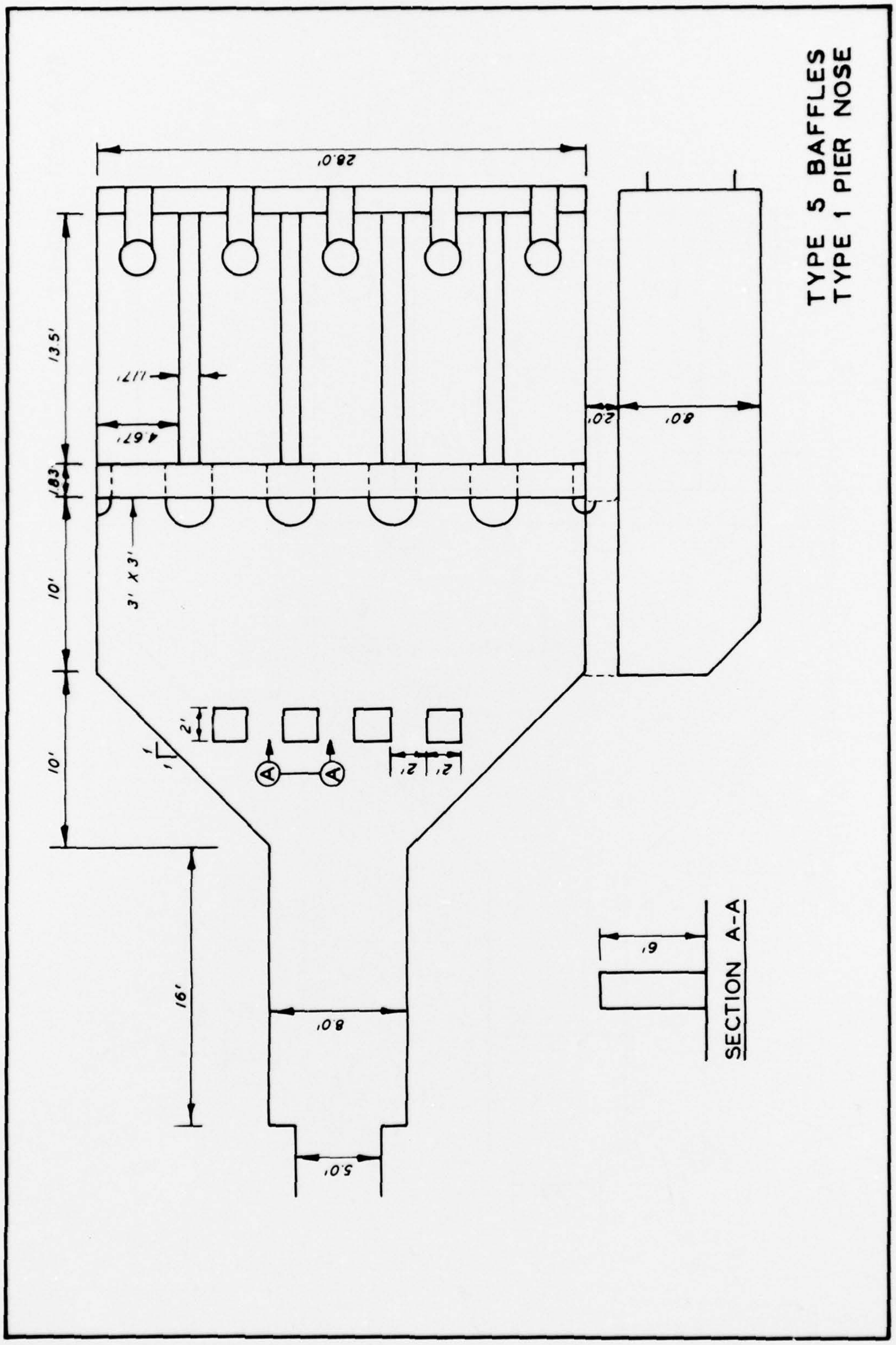
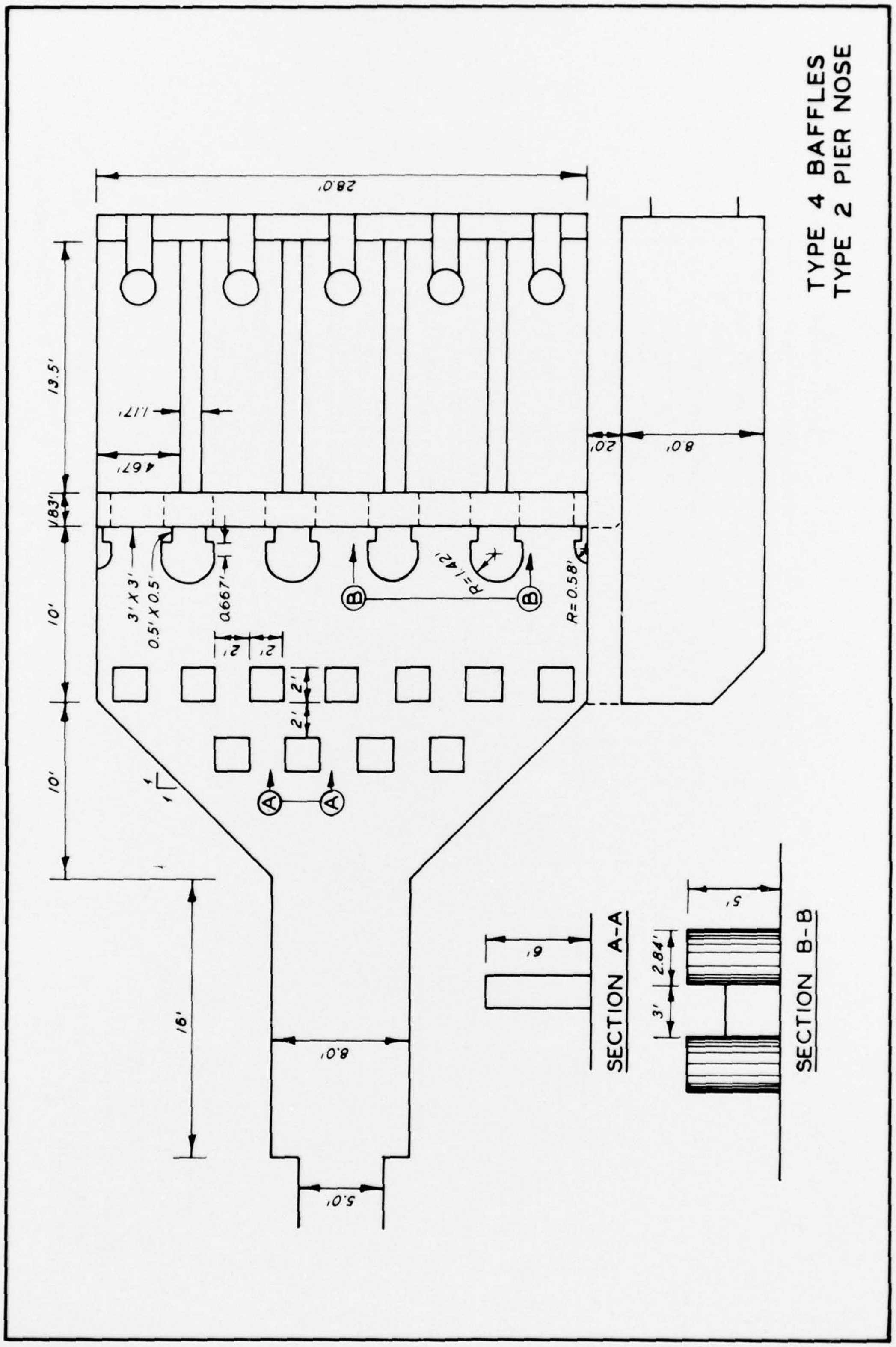

TYPE 4 BAFFLES
28.0'
13.5'
1.17'
4.67'
1.83'
2.0'
8.0'
10'
3' X 3'
2'
2'
2'
2'
10'
1
1
A
A
16'
8.0'
5.0'
SECTION A-A
6'

PLATE 8



TYPE 1 PIER NOSE
28.0'
13.5'
1.17'
4.67'
1.83'
2.0'
8.0'
R=0.83'
3 X 3'
R=1.42'
A
A
10'
10'
16'
8.0'
5.0'
SECTION A-A
3'
2.84'
3'


TYPE 5 BAFFLES
TYPE 1 PIER NOSE
28.0'
13.5'
1.17'
4.67'
2.0'
8.0'
1.83'
3' X 3'
10'
10'
2'
2'
2'
16'
8.0'
5.0'
6'
SECTION A-A



TYPE 4 BAFFLES
TYPE 2 PIER NOSE

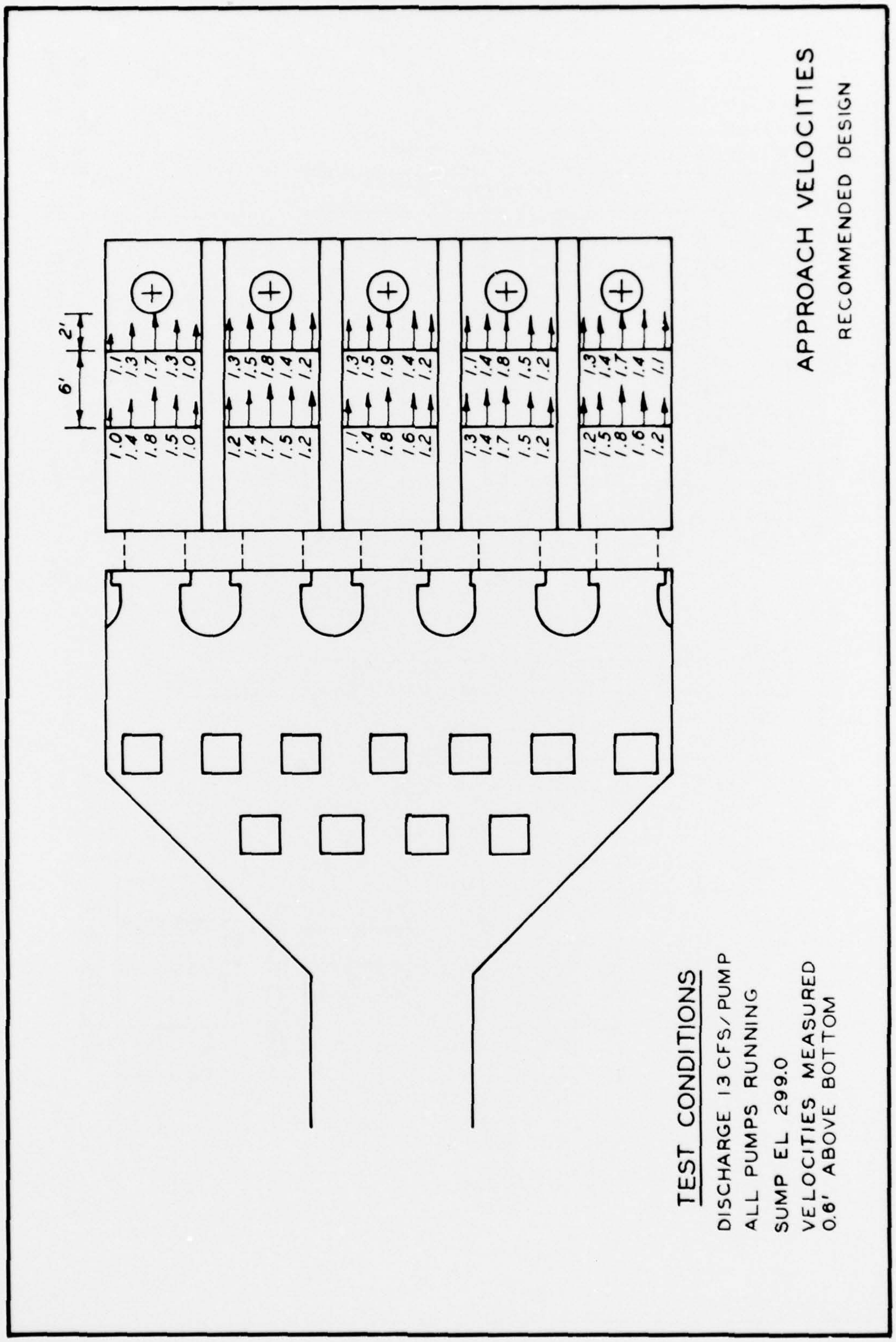

APPROACH VELOCITIES
RECOMMENDED DESIGN
6'
2'
1.1 1.3 1.7 1.3 1.0
1.0 1.4 1.8 1.5 1.0
1.3 1.5 1.8 1.4 1.2
1.2 1.4 1.7 1.5 1.2
1.3 1.5 1.9 1.4 1.2
1.1 1.4 1.8 1.6 1.2
1.1 1.4 1.8 1.5 1.2
1.3 1.4 1.7 1.5 1.2
1.3 1.4 1.7 1.4 1.1
1.2 1.5 1.8 1.6 1.2
TEST CONDITIONS
DISCHARGE 13 CFS/PUMP
ALL PUMPS RUNNING
SUMP EL 299.0
VELOCITIES MEASURED
0.6' ABOVE BOTTOM

PLATE 12

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Fletcher, Bobby P
Flow conditions at pumping stations, Cairo, Illinois; hydraulic model investigation, by Bobby P. Fletcher [and] John L. Grace, Jr. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report H-77-3)
Prepared for U. S. Army Engineer District, Memphis, Memphis, Tennessee.

1. Flow. 2. Hydraulic models. 3. Pumping plants. 4. Pumps. I. Grace, John Linson, joint author. II. U. S. Army Engineer District, Memphis. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report H-77-3)
TA7.W34 no.H-77-3