ADDENDUM TO
HYDRAULIC MODEL STUDY OF THE
SUCTION BASIN OF DRAINAGE PUMPING STATION NUMBER 7
SEWERAGE AND WATER BOARD OF NEW ORLEANS

by

Dean K. White

Submitted to

PEPPER & ASSOCIATES, INC.

ALDEN *Solving Flow Problems Since 1894*

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HYDRAULIC MODEL STUDY OF THE
SUCTION BASIN OF DRAINAGE PUMPING STATION NUMBER 7
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The hydraulic model study of Drainage Pumping Station No. 7 conducted in 2002 evaluated the existing suction basin configuration and a proposed configuration that added a new box culvert parallel to and east of the Orleans Canal. In addition, Pumps 1, 2 and 3 were to be replaced by three 300 cfs centrifugal pumps drawing water from the suction basin through the existing 8 ft diameter conduits fitted with reducing suction elbows to connect to the pumps. With the invert of the existing 8 ft diameter intake conduit at El. 1.0 Board Datum (BD), the low point of the suction elbow crown would be at El. 7.84 ft (BD) and the centrifugal pump suction flange would be at approximately El. 10.5 ft (BD).

The Sewerage and Water Board estimated that these pumps could only operate down to suction basin El. 11.0 ft (BD) and, therefore, requested a study to redesign the pump station to reduce the lower limit of the operating range with the use of vertical wet pit pumps. Pepper and Associates, Inc. requested the assistance of Alden Research Laboratory, Inc. (Alden) to lay out and test an intake bay for use with each of the three proposed vertical pumps. The intake bays were limited in size and shape by the configuration of the existing pumping station. The existing 8 ft diameter conduits could be widened but the 8 ft height and invert elevation could not be altered. Downstream of the conduits, the openings in the station floor at El. 24.0 ft (BD) formed the outer limit of the boundary of the proposed intake bays.

Considering the constraints of the existing station and the capacity of the pumps, Alden developed the configuration of the intake bays. The 8 ft diameter circular conduits were replaced with box culverts 10 ft wide by 8 ft high extending from the suction basin to the existing pits. The proposed vertical pump intake bays were configured to gradually expand from the 10 ft wide conduit to a width of 17 ft, while remaining inside of the existing openings in the floor, see Figures A1 and A2. Generally 300 cfs vertical wet pit pumps have a bell diameter between 90" and 115". For this study, a 100" bell was selected and an intake bay width of 17 ft (204") is approximately two pump bell diameters as recommended in the Hydraulic Institute (HI) pump intake design standards.

The physical model was constructed to a 1 to 12.5 scale to simulate the intake bay of Pump 2 and a portion of the suction basin, centered on Pump 2, measuring 100 ft along the face of the pump station and extending 50 ft out into the basin, see Figure A3. Flows to simulate the operation of Pumps 1 and 3 were removed through the pump station wall at the appropriate locations. As discussed in the model study report, Pump 2 was evaluated in the model because the short length of conduit (8 ft) leading to the pump will not isolate the pump as well from the variable flow conditions in the suction basin as the longer conduits leading to Pumps 1 and 3 (27 ft).

TABLE A1

TEST MATRIX INITIAL DESIGN

Test #	Pump Flow (cfs)			Basin El. ft (BD)
	1*	2	3*	
1	0	300	0	9.5
2	0	300	300	9.5
3	300	300	0	9.5
4	300	300	300	9.5

*Intake not modeled/flow simulated.

The initial test matrix was developed with four pump combinations at suction basin El. 9.5 ft (BD), see Table A1. Operation under conditions 1 and 4 indicated that there was unacceptable surface and subsurface vortex activity at the pump bell and flow separation at the entrance to the 10 ft by 8 ft box culvert. In the intake bay, a fillet was added between the floor and the wall and a cone was placed on the floor below the pump bell to limit subsurface vortex activity. Roundings were added to the face of the pump station to reduce separation at the entrance to the box culvert. The fillet and cone prevented Type 2 and higher submerged vortex activity and the roundings on the face of the pump station prevented separation at the entrance to the box culvert.

Surface vortex activity remained at an unacceptable level, as high as Type 5 and swirl in the pump column was above 5 degrees under test Condition 2, see Table A2. A curtain wall was installed at the exit of the box culvert to reduce surface vortex activity. Swirl angle in the pump was reduced by replacing the cone below the pump bell with a triangular splitter extending upstream to the downstream face of the curtain wall and attaching a vertical splitter plate to the back wall of the intake. The position of the bottom edge of the curtain wall was adjusted until the velocity of the backflow across the water surface downstream of the curtain wall was high enough to prevent surface vortex formation near the pump column. Surface vortex activity limited to Type 2 was achieved with the lower edge of the curtain wall set at El. 6.5 ft (BD). The wall was positioned as high as possible to maximize the approach flow area.

TABLE A2

SWIRL ANGLE PUMP 2 WITH ONLY

WALL TO FLOOR FILLET AND CONE INSTALLED

Test #	Average Swirl Angle	Maximum Swirl Angle
1	1.4	3.6
2	5.4	7.2
3	0.7	2.4
4	3.1	4.8

The final configuration of the intake structure is shown in Figures A4 and A5 and the structure was evaluated under the five conditions listed in Table A3. The roundings applied to the pump station wall prevented separation at the entrance to the 10 ft by 8 ft box culvert under all test conditions. For each of the test conditions, surface vortex activity was Type 2 or less and subsurface vortex activity was limited to Type 1. All swirl angles were acceptable, with the highest average swirl angle 2.3 degrees and the highest maximum 10 second swirl angle 3.6 degrees, see Table A4.

TABLE A3

TEST MATRIX FINAL CONFIGURATION

Test #	Pump Flow (cfs)			Basin El. ft (BD)
	1*	2	3*	
1	0	300	0	9.5
2	0	300	300	9.5
3	300	300	0	9.5
4	300	300	300	9.5
5	0	300	0	8.5
6	0	300	0	**

*Intake not modeled/flow simulated.
**Determine lowest acceptable operating level.

TABLE A4

SWIRL ANGLE PUMP 2 WITH

FINAL INTAKE BAY CONFIGURATION

Test #	Average Swirl Angle	Maximum Swirl Angle
1	1.2	3.6
2	2.3	3.6
3	0.8	2.4
4	1.2	2.4
5	0.9	2.4

The velocity distribution at the throat of the bell was obtained with a 33 point traverse. The distribution using Pump Bell Configuration 1, see Figure A6, shows a large region of low velocity approaching the pump impeller at the side of the pump facing the curtain wall. The HI Standards call for each point velocity to be within 10% of the normalized velocity, i.e., ranging from 0.9 to 1.1. The points in the region of low velocity are considerably lower than 0.9, see Figure A7. A number of factors contribute to the skew ness of the velocity distribution. Due to the constraints of the existing pump station, the intake structure is smaller than that recommended by the HI Standards for a 300 cfs vertical pump resulting in a higher velocity approaching the pump. The pump simulated in the model represented a 100" diameter bell but the profile, as Figure A6 shows, contains several abrupt angle changes and the diameter of the throat was relatively large in comparison with bell diameter. To determine if the selection of a bell affects the throat velocity distribution, a second bell, Pump Bell Configuration 2, representing a 100" diameter bell with a slightly smaller throat and a much more streamlined bell profile, see Figure A8, was tested in the intake structure under the same operating condition. The velocity distribution at the throat of the bell was significantly improved with all point velocities within 10% of the normalized velocity, see Figure A9. These bells were constructed for and successfully tested in separate model studies with the intake bays constructed to dimensions recommended by the HI. When the intake bay does not conform to the HI Standards, the shape of the pump bell becomes more important in developing an acceptable velocity profile at the throat of the bell.

To determine the lowest operating level, the suction basin water elevation was reduced below El. 8.5 ft (BD). As the water level dropped, the velocity in the intake increased and at El. 8.0 ft (BD), an intermittent Type 5 surface vortex appeared approximately 15 percent of the time between the pump column and the back wall. As the water level approached El. 7.7 ft (BD), the turbulence level was high enough that air entrained in the water as the water discharge from under the curtain wall, remained in the water as it entered the pump. The high turbulence, however, prevented further vortex formation. As the water level continued down, increasing amounts of air were entrained into the pump.

CONCLUSIONS AND RECOMMENDATIONS FOR THE USE OF WET PIT PUMPS

1. Each intake bay should be constructed in accordance with Figure A4.

2. The length of the 10 ft wide by 8 ft high box culvert will vary based on the position of the pit remaining from the old centrifugal pumps.

3. The dimensions of the intake bays are based on a 100" diameter bellmouth, therefore, the bellmouth diameter should be specified when ordering the pump.

4. The test program shows that the suction basin can be as low as El. 8.0 ft (BD) with only occasional surface vortex activity.

5. The velocity measurements obtained at the throat of the bell illustrate the importance of the bell profile. Unless the pump selected for use has a bell similar to the profile of Pump Bell Configuration 2, see Figure A8, it should be evaluated in the hydraulic model.

FIGURES

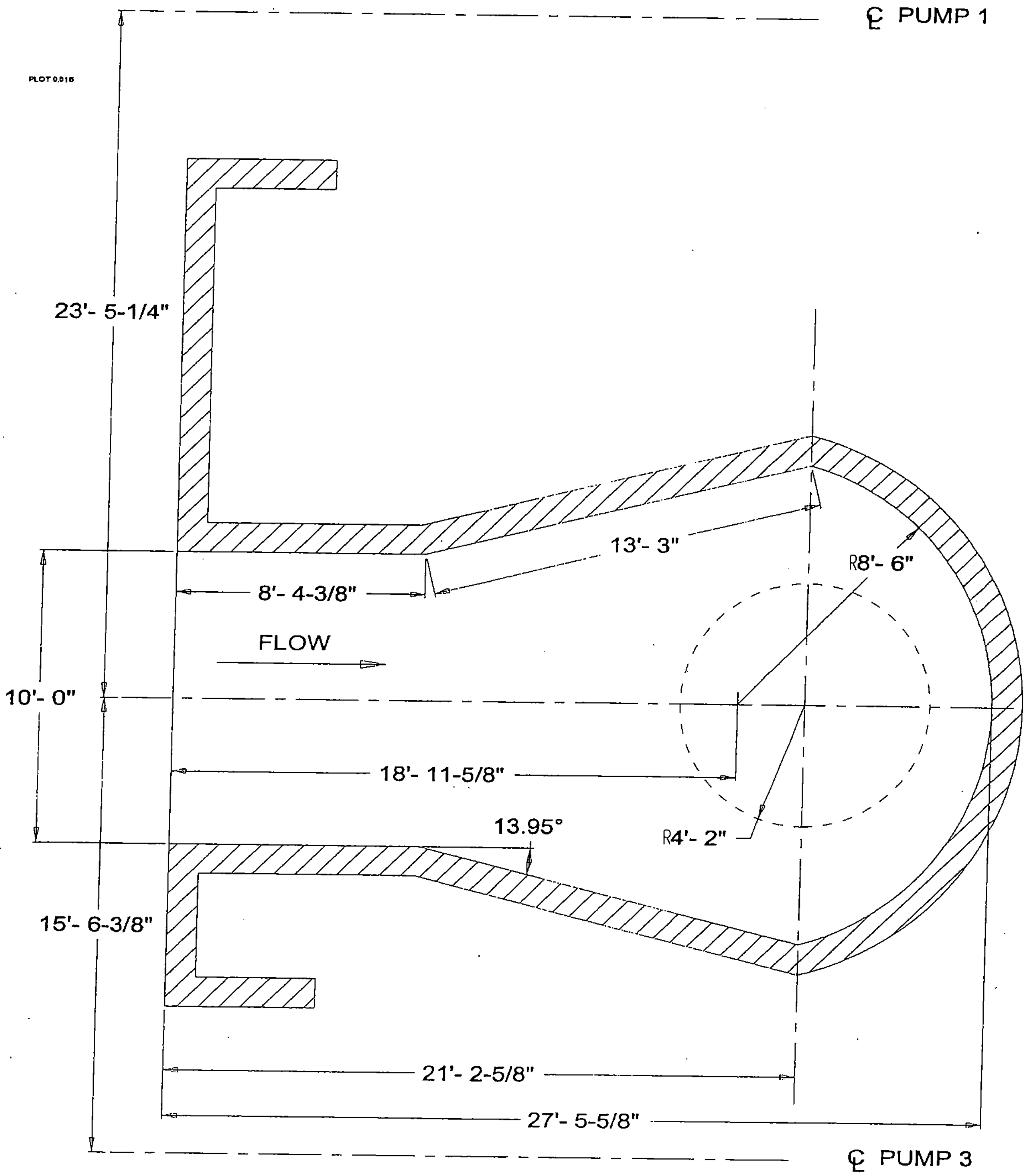

FIGURE A1 LAYOUT OF PUMP 2 INTAKE

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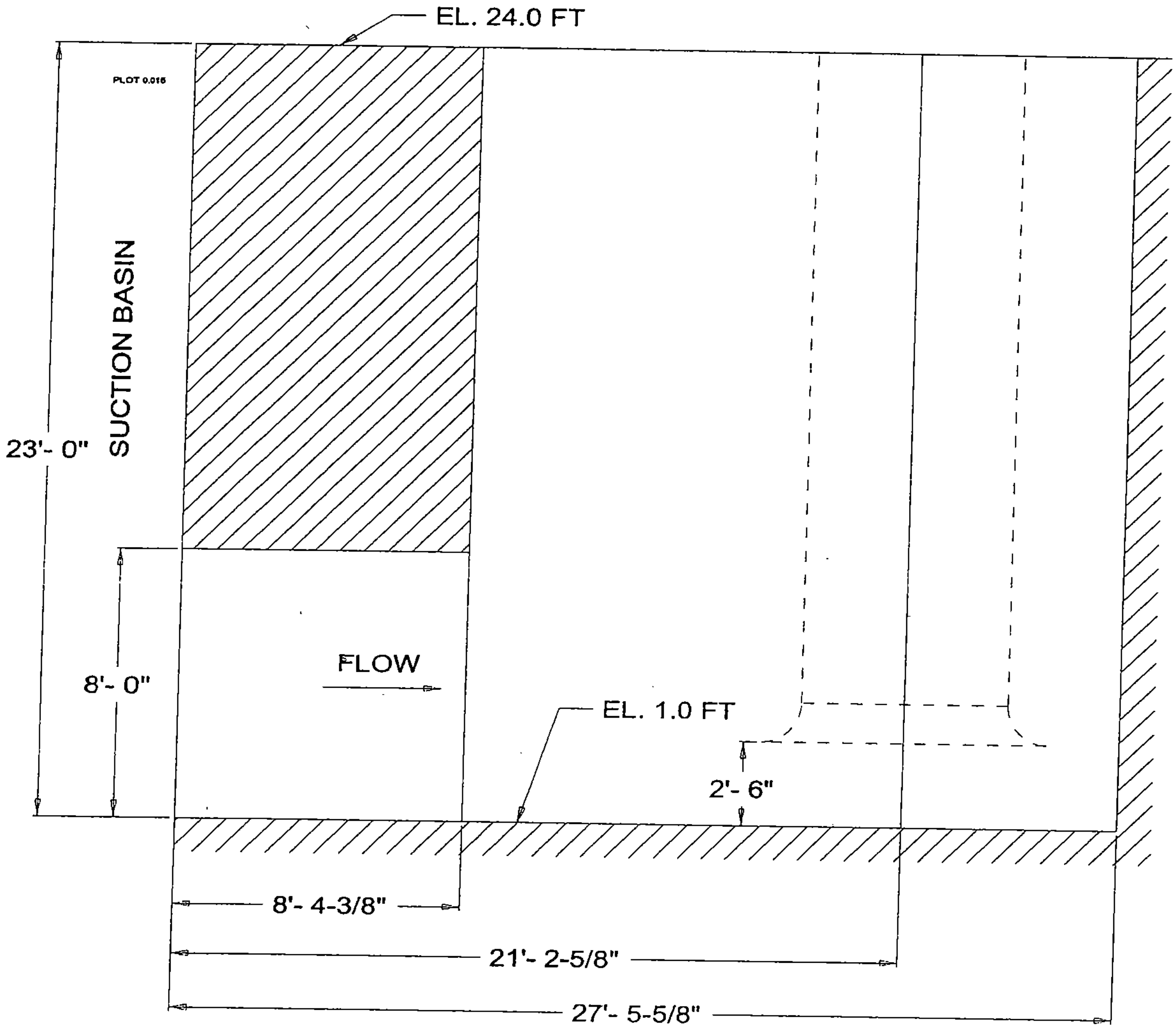

FIGURE A2 ELEVATION OF PUMP 2 INTAKE

ALDEN

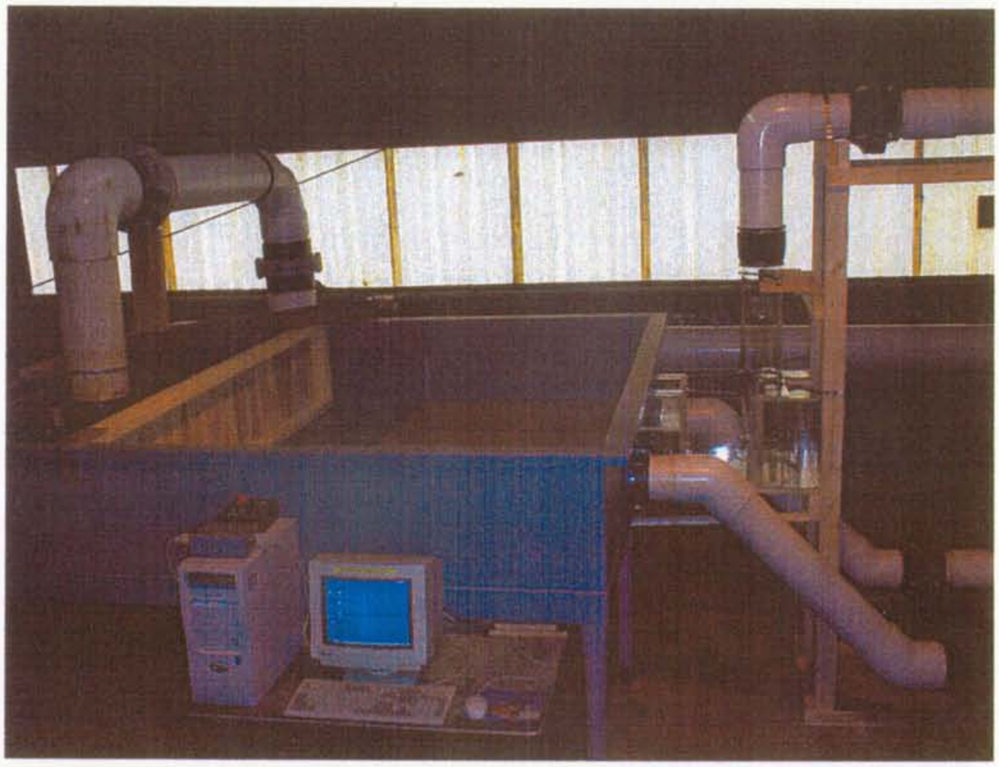

FIGURE A3 MODEL OF PUMP 2 INTAKE

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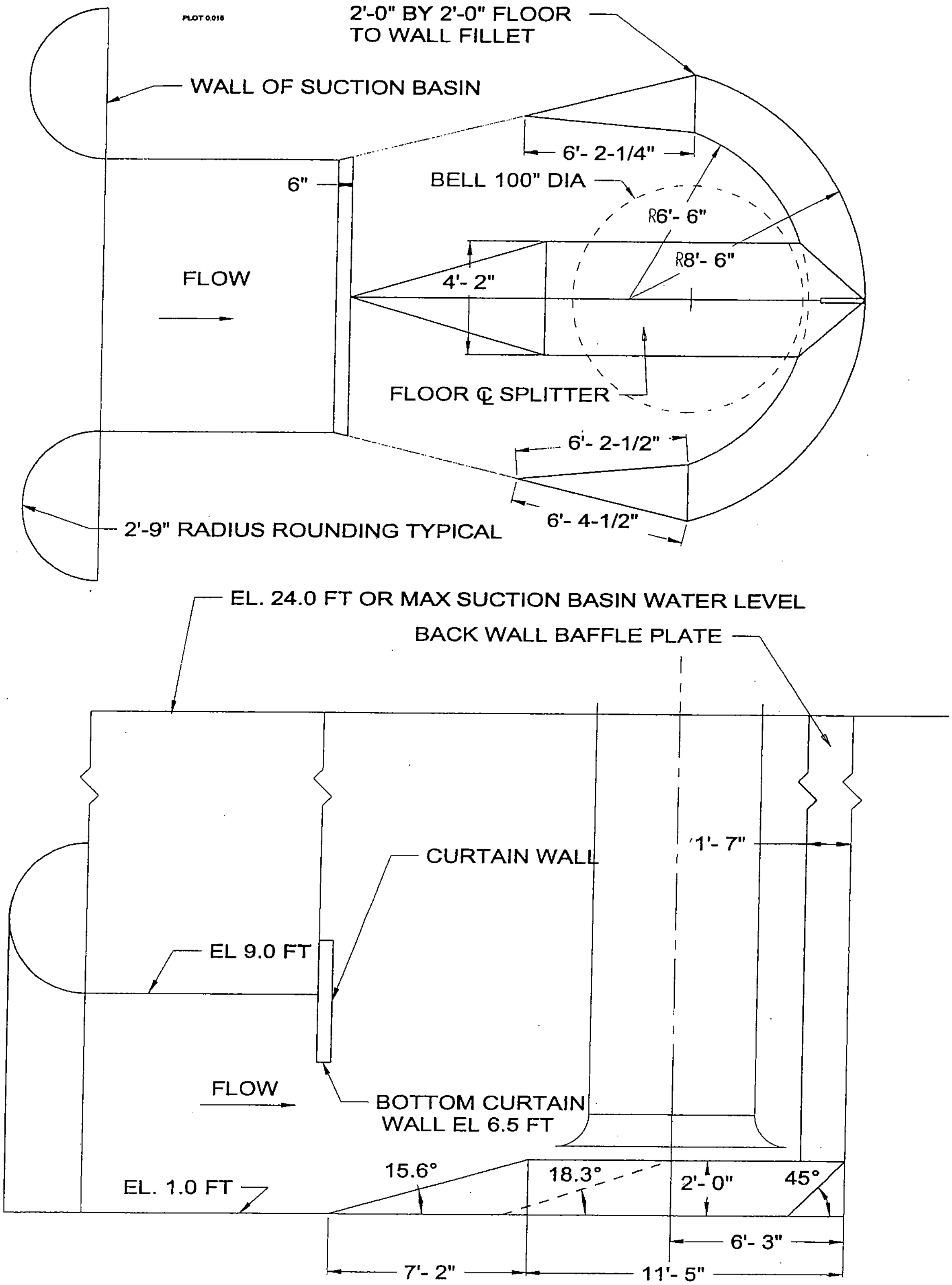

FIGURE A4 RECOMMENDED INTAKE BAY CONFIGURATION
PUMP 2

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FIGURE A5 RECOMMENDED INTAKE BAY CONFIGURATION

ALDEN

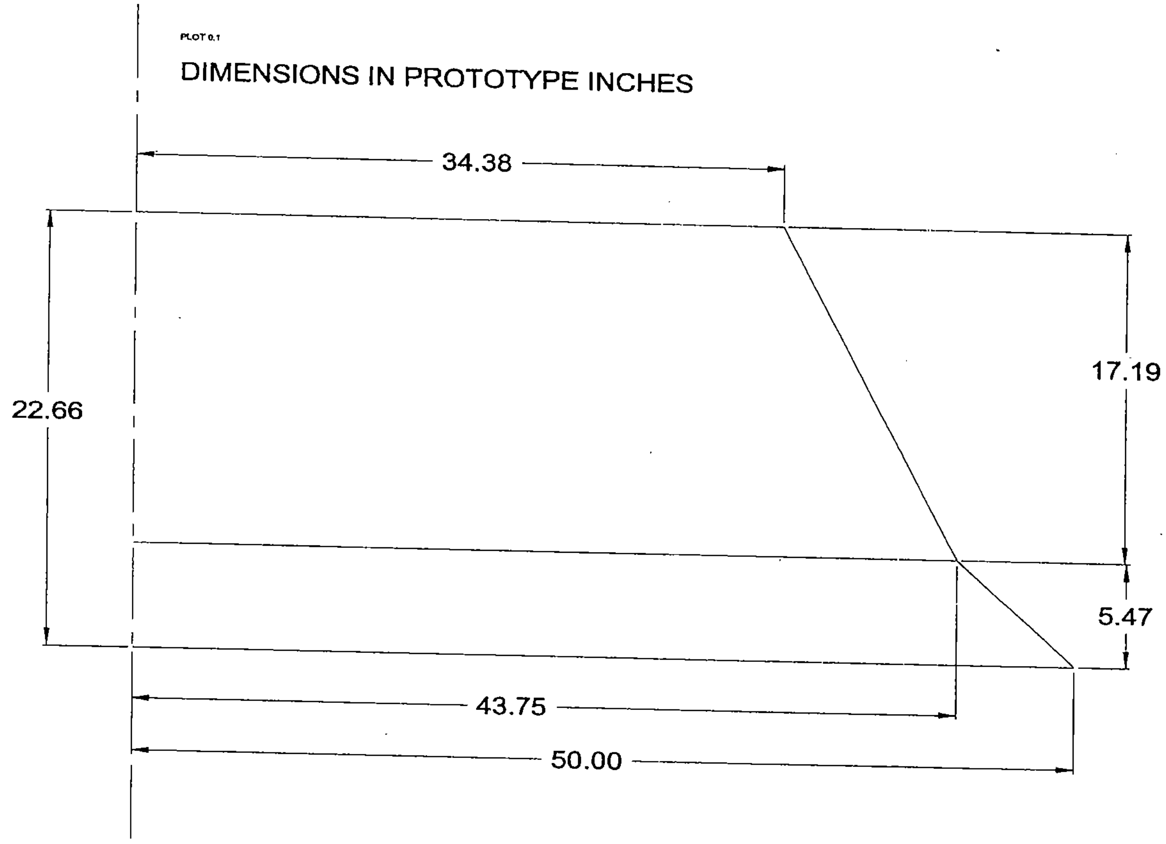

FIGURE A6 BELLMOUTH CONFIGURATION 1

ALDEN

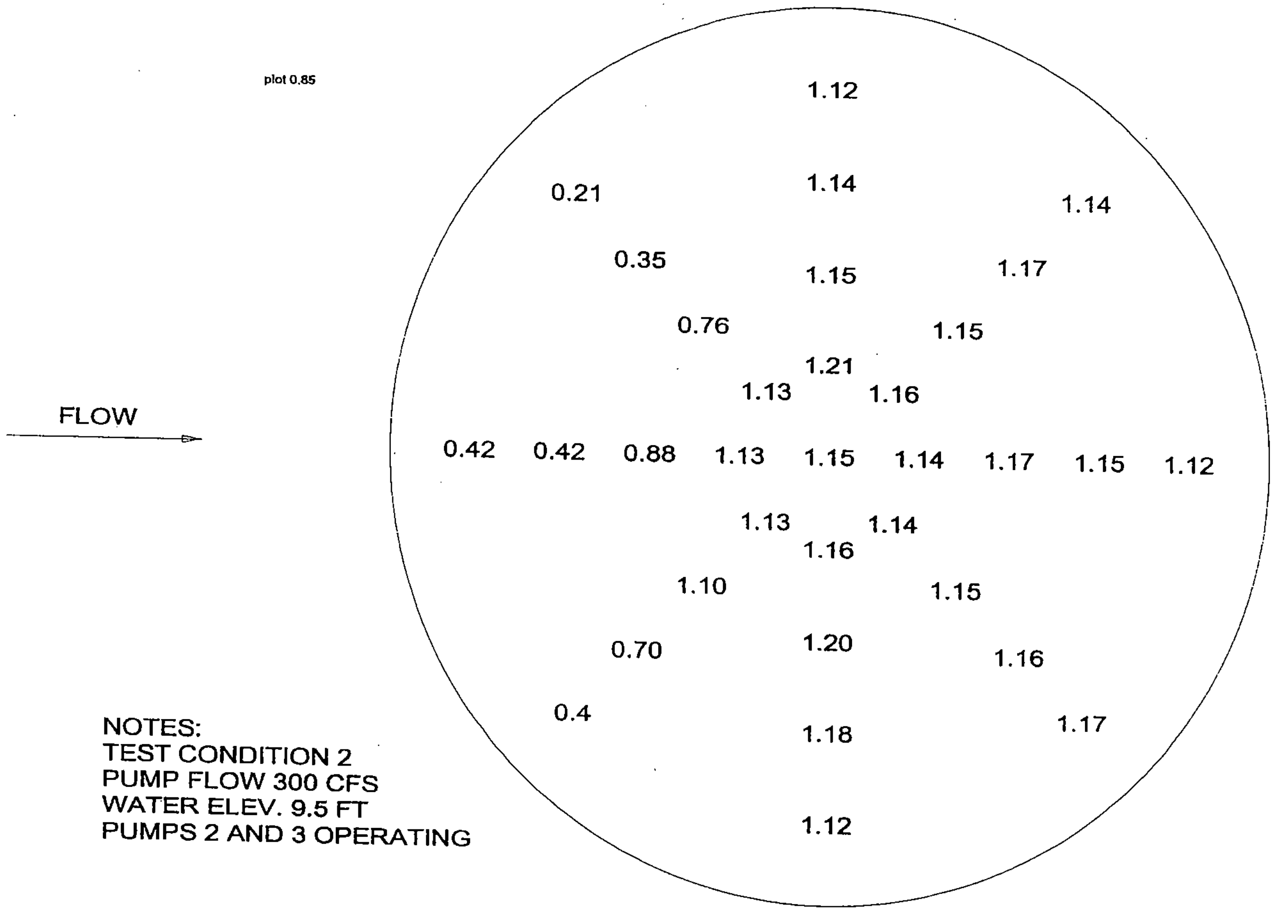

FIGURE A7 NORMALIZED THROAT VELOCITY DISTRIBUTION
BELL CONFIGURATION 1

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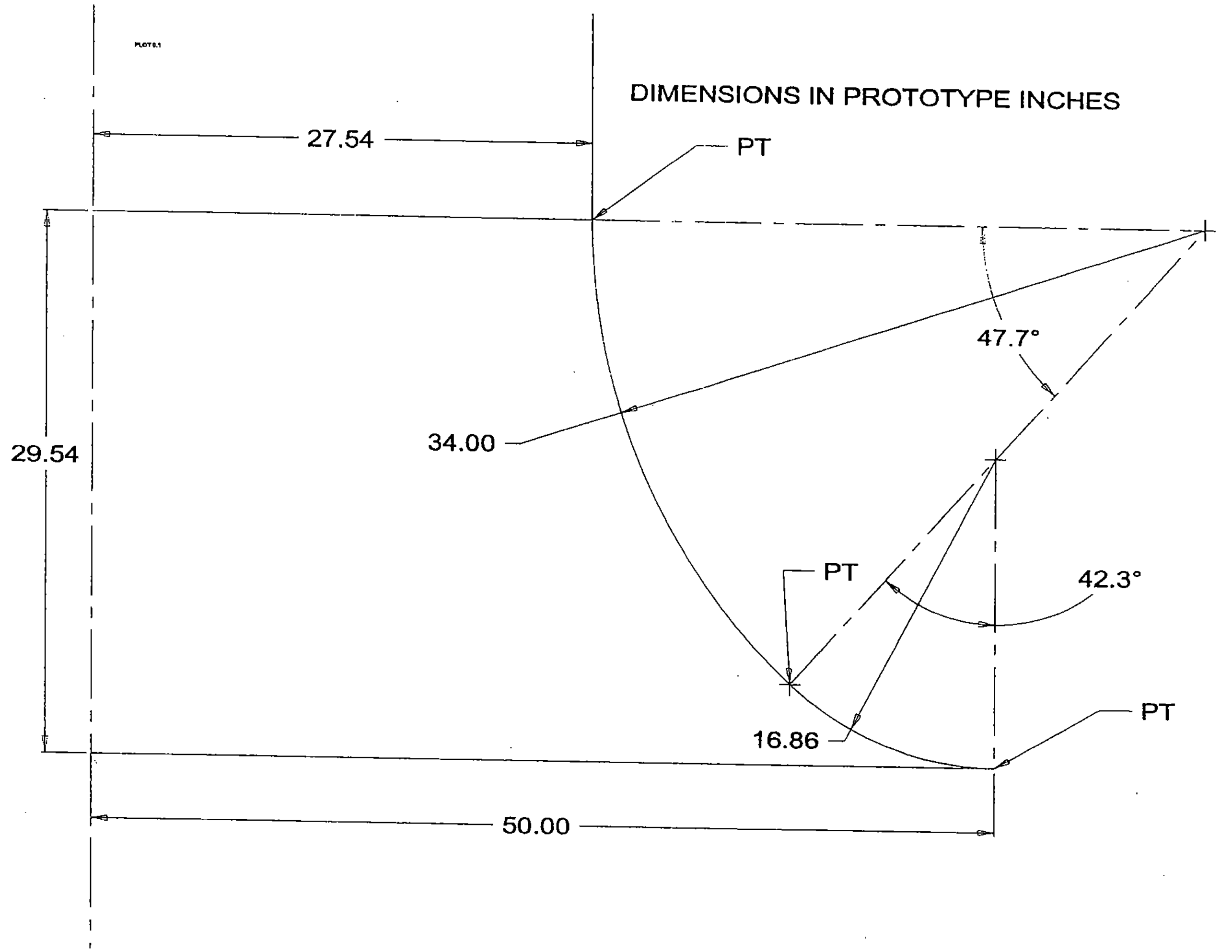

FIGURE A8 BELLMOUTH CONFIGURATION 2

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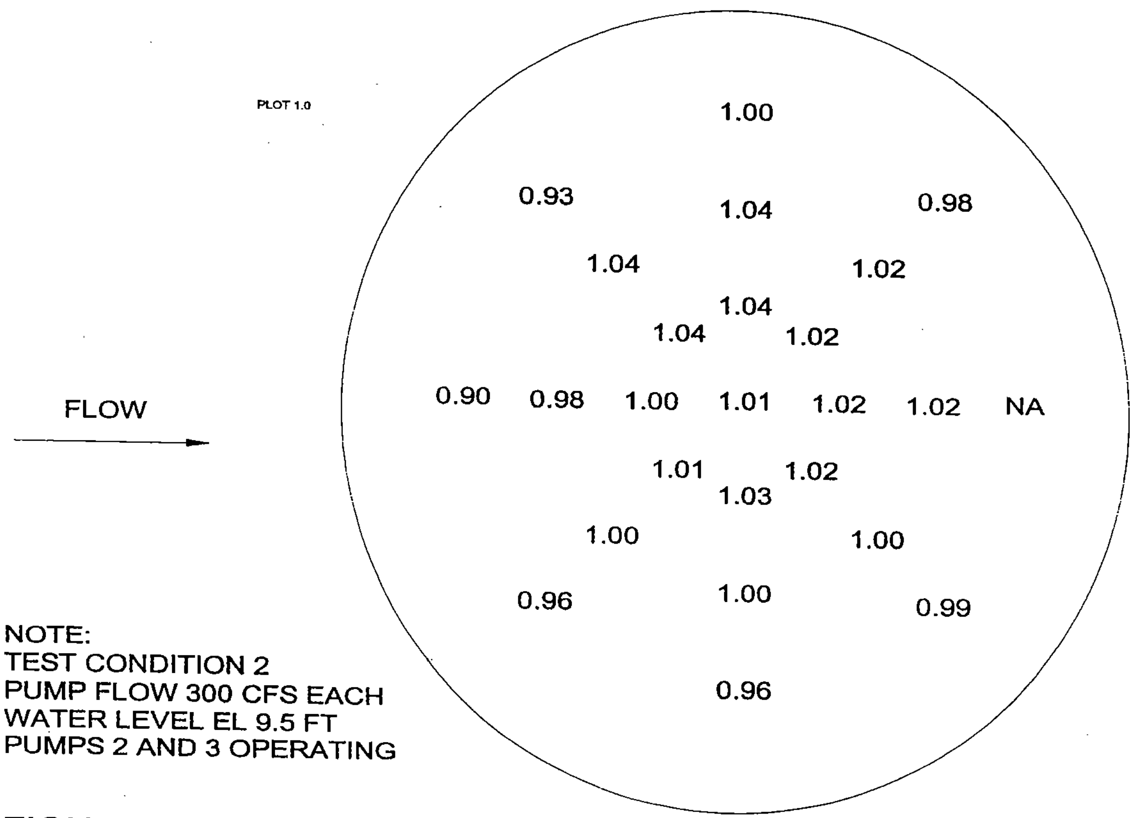

NOTE:
TEST CONDITION 2
PUMP FLOW 300 CFS EACH
WATER LEVEL EL 9.5 FT
PUMPS 2 AND 3 OPERATING

FIGURE A9 NORMALIZED THROAT VELOCITY DISTRIBUTION
BELL CONFIGURATION 2

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