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Gas removal systems, Phase B: Part I formation of test program, December 1964

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LEHIGH UNIVERSITY INSTITUTE OF RESEARCH

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Dredge Pump Research

Gas Removal Systems
Phase B:Part 1
Formulation of Test Program
Development of Facility Layout

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Fritz Engineering Laboratory Report No. 310.5

CIVIL ENGINEERING DEPARTMENT
FRITZ ENGINEERING LABORATORY

GAS REMOVAL SYSTEMS
PHASE B: PART 1
FORMULATION OF TEST PROGRAM
DEVELOPMENT OF FACILITY LAYOUT

Status Report No. 4

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ABSTRACT

A proposed test program is presented and discussed for carrying out an experimental study of gas removal from dredging suction lines. Several series of tests and the sequence of tests within each series are planned. The parameters to be studied are determined and classified as dependent and independent parameters.

Development of the facility layout, determination of space requirements for both the test facility and the physical arrangement of apparatus, and a list of components needed is also included in this report.

PREFACE

The following status report summarizes the studies performed under Part 1, Phase B of the project during the period October 15, 1964 to December 1, 1964, at the Hydraulic and Sanitary Engineering Division of Fritz Engineering Laboratory, under term of Contract No. DA-36-109-CIVENG-64-72. The progress on the study was reported in three status reportes dated February 1964, April 1964, and October 1964 (Fritz Laboratory Reports No. 310.1(1)*, No. 310.2(2)*, and No. 310.4(3)*) respectively and in a project report dated June, 1964 (Fritz Laboratory Report No. 310.3(4)*).

Phase A of the project was completed and summarized in the project report No. 310.4, dated June 1964.

Dr. John B. Herbich is the Project Director, and Dr. Adnan Shindala is the Project Supervisor. They are assisted by Instructor A. Amatangelo and Research Assistant G. Bagge. Professor W. J. Eney is Head of the Department of Civil Engineering and Fritz Engineering Laboratory, and Dr. L. S. Beedle is the Director of Fritz Engineering Laboratory.

*Numbers in parenthesis refer to references on page 15.

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I INTRODUCTION

This report describes the work performed under Part 1, Phase B of the project between the U. S. Army Corps of Engineers and the Hydraulic and Sanitary Engineering Division of Lehigh University which pertained to conducting a study on gas removal systems for dredge pumps. The scope of the work specified under Phase B of the Project was subdivided into two parts as follows:

PART 1

Part 1 consisted of developing a test program; planning the different series of tests and the sequence of tests within each series; determining the parameters to be studied; distinguishing between dependent and independent variables; developing the facility layout; determining space requirements for the test facility and for the physical arrangement of apparatus; determining the components needed in the test setup; developing special facility details; establishing piping layout; designing special pipe details, tanks, foundations, and other structures; designing instrumentation and controls; setting forth the specifications for special equipment; developing detailed, step-by-step test procedures, including sequence of operations, adjustments, and readouts; laying out data sheets; and naming the curves to be plotted for study.

PART 2

Part 2 shall consist of developing a complete test schedule. The schedule shall be in the form of a bar graph for each separable test or series of tests. Bar graphs shall be on a time scale of (x) days from the time zero (which will be the date of receipt of Notice to Proceed with

Phase C). The bar graphs shall indicate notable milestones. A scale of percentage of completion shall also be carried along each graph.

II TEST PROGRAM

A. DISCUSSION

A test program for the study of gas removal from the suction side of a dredge pump is presented here. It should be kept in mind that the formulation of this program was based entirely on a theoretical analysis of the problem of gas removal and that the program is considered to be quite flexible as to how certain operations will be performed as the project unfolds.

Gases in dredged materials occurs in two distinct forms:

(1) As free gas which is usually trapped due to the effect of liquid viscosity and enters the suction line of the pump without opportunity to escape to the atmosphere; and,

(2) As dissolved gas in the liquid but which comes out of solution when the suction pressure is decreased below atmospheric pressure. The volume of dissolved gas coming out of solution in the suction line depends upon the negative or vacuum pressure in that line.

In the laboratory, two types of gas injection could be used:

(1) A water mixture that has been saturated to a high percentage with carbon dioxide gas (CO_2) under a hydrostatic head is released in the suction line by decreasing the pressure, or,

(2) A controlled rate of free gas (CO_2) is injected into the suction line.

However, it is believed that the first procedure will significantly complicate monitoring both the amount of gas liberated and the total flow of gas, which will result in less accurate results. Thus, the second procedure is recommended, and free gas will be injected at some point along the suction line. The location of gas injection will probably be as close as possible to the suction drag head.

B. TEST SETUP

The following model test setup is presented in general form:

(1) Dredge pump, bronze-Plexiglas (Figure 5)

(2) Suction piping, Plexiglas (Figure 3)

(3) Accumulator, Plexiglas

  (a) Cylindrical accumulator (Figure 7)

  (b) Vortex accumulator (Figure 8)

(4) Vacuum pumps

(5) Vacuum control equipment

(6) Discharge piping, steel with transparent sections (Figure 4)

(7) Suction volumetric tank, (Figure 1)

(8) Discharge volumetric tank, (Figure 1)

(9) Measuring equipment for:

  (a) Vacuum

  (b) Pressure

  (c) Speed

  (d) Rate of flow

  (e) Power input

(10) Gas, carbon dioxide (CO_2), including:

  (a) Injection device

  (b) Metering device

  (c) Control device

Note: (For more detail description of the above equipments see "Facility Layout", page 10).

C. TEST SERIES NO. 1

In the first test series of this study general observations will be made of carbon dioxide gas injected at a controlled rate into the suction-line. The gas will accumulate in the discharge tank from where it will be removed.

1. Objects

The main objects of this series will be:

(a) To study the general behavior of the carbon dioxide gas in the suction system while clear water only is the fluid medium; this will include the rise, expansion, and position, of the gas bubbles as they proceed through the suction line;

(b) To assist in selecting effective positions for the gas accumulator;

(c) To aid in developing a workable model;

(d) To provide a reference for comparing the performance of the system with and without the gas-removal equipment; and,

(e) To determine the ~~amount~~ relationship of gas, pump speed, and rate of flow that will cause a complete collapse of the dredge pump. This added at request of GA Johnson, Hr 22 Sept 64.

2. Parameters

(1) Gas content (cfs)

(2) Speed (rpm)*

(3) Rate of flow (cfs)*

3. Procedure

Accumulator, vacuum pump and control equipment are not used in this series.

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*It is anticipated that tests will be conducted for at least three speeds and three rates of flow.

(1) Operate the dredge pump at a certain speed and rate of flow.

(2) Inject carbon dioxide gas into the suction line at a certain rate.

(3) Observe the action, such as rise, expansion, position, and size, of the gas bubbles in the suction system.

(4) Note gauge readings of control parameters, such as voltage, amperage, velocity, pressure,

(5) Repeat program for different content of gas, holding speed and rate of flow constant. Note the amount of gas which causes complete collapse, if any, of dredge-pump suction at each gas content and flow rate.

(6) Repeat program for different flow rates, holding the amount of gas and the speed constant. Note the rate of flow which causes complete collapse, if any, of the dredge-pump suction at each speed and gas content.

(7) Repeat program for different speeds, holding the amount of gas and the rate of flow constant.

4. ANALYSIS

(1) Calculate the efficiency of the pump at each speed, gas content, and flow rate.

(2) Plot the curves:

(a) Pump efficiency as a function of gas content for different speeds and flow rates.

(b) Pump efficiency as a function of flow rate for different speeds and gas contents.

(c) Pump efficiency as a function of speed for different flow rates and gas contents.

(3) On the bases of the above curves and analysis of the data obtained in this series determine:

(a) The combination of gas content, speed, and flow rate that will result in the lowest as well as the highest pump efficiency.

(b) The amount of gas that should be removed by means of an accumulator in order to obtain maximal pump efficiency.

(c) Several probable effective positions of the gas accumulator.

D. TEST SERIES NO. 2

1. Objects

The main objects of this series will be:

(a) To verify by test the initial positions for the gas accumulator as suggested by observations in Test Series No. 1, and to select one optimal position that will result in highest efficiency;

(b) To compare the efficiency of the dredge pump with and without gas removal system at different speeds, gas contents, and flow rates; and

(c) To compare the efficiency of a cylinder accumulator with that of a vortex accumulator.

2. Parameters

(1) Location of accumulator along the suction line.

(2) Gas content (cfs)

(3) Speed (rpm)

(4) Rate of flow (cfs)

3. Procedure

A. (1) Place the cylindrical accumulator in one position and connect to the vacuum pump.

(2) Operate the dredge pump.

(3) Operate the vacuum pump.

(4) Control the vacuum so as to prevent liquid carryover into the vacuum pump, or to regulate the height of fluids in the accumulator.

(5) Repeat program of Test Series No. 1, with the accumulator in operation.

(6) Repeat above program for other positions of the accumulator.

B. (1) Repeat procedure (A) for the vortex accumulator (Figure 6).

4. ANALYSIS

(1) Calculate the efficiency of the pump with the cylinder accumulator in place at different speeds, gas contents, and flow rates.

(2) Plot the curves:

(a) Pump efficiency as a function of gas content for different speeds and flow rates with the accumulator at certain positions (say x_1).

(b) Pump efficiency as a function of flow rate for different speeds and gas contents with the accumulator at the same position, x_1.

(c) Pump efficiency as a function speed for different gas contents and flow rates, and with the accumulator at the same position,

(d) Repeat parts (a), (b), and (c) with the accumulator at different positions.

(3) From the comparison of these curves with those obtained under Test Series No. 1, determine the optimal position of the accumulator.

(4) Determine the efficiency of the accumulator (per cent CO_2) removed), by measuring the portion of the gas not removed and accumulated in the discharge tank, at different positions of the accumulator, and plot efficiency as a function of position.

(5) Repeat the same analysis for the vortex accumulator.

E. SERIES NO. 3

1. Object

The object of this series is to determine the effect of several parameters on the performance of the gas-removal system with the accumulator positioned as determined from Test Series No. 2.

2. Parameters

(1) Gas content (cfs)

(2) Dredging depth (ft.)

(3) Density (slugs/ ft^3)

(4) Rate of flow (cfs)

(5) Discharge head (ft)

(6) Vacuum pressure at gas removal pump (ft)

(7) Gas accumulator fluid level (ft)

(8) Speed (rpm)

3. Procedure

(1) Repeat the program of Test Series No. 2, varying all the above parameters throughout their ranges, but only one at a time, to isolate the effect of each.

4. Analysis

(1) Plot curves noting the interrelationship between parameters for example, effect of gas volume at several densities, vacuum pressure of gas-removal pump, and level of gas accumulator. Data recorded, in addition to the above parameters shall include voltage, amperage and vacuum, and discharge pressures.

Note: Test Series No. 1, 2, and 3 will be performed on clear water only.

III FACILITY LAYOUT

A. DISCUSSION

Figures 1 and 2 show the facility layout. The material will be dredged from the suction volumetric tank of 350 cubic feet capacity and discharged into the discharge volumetric tank of 340 cubic feet capacity. In order to insure continuous flow, the two tanks are connected with a 10-inch pipe equipped with a gate valve for controlling the flow. This particular setup is preferred because it eliminates the possibility of recirculating the excess gas not removed by the accumulator. This excess gas will accumulate in the discharge tank B, from which it will be evacuated and passed through a metering device. This procedure will also permit a more accurate determination of the efficiency of the accumulator. Two types of accumulators, cylinder accumulator and vortex accumulator, will be used. Both accumulators are transparent and will be connected to a vacuum pump. Carbon dioxide gas will be used and injected at a point along the suction line close to the drag head. The rate of injection of this gas will be measured.

B. EQUIPMENT

(a) Equipment available in the Hydraulic Laboratory include:

(1) Magnetic flow meter

(2) Strobotac

(3) Tachometer

(4) 40-hp D.C. motor

(5) Two volumetric tanks, A and B, (Figures 1 and 2)

(6) Bearings

(7) Dynalog recorder

(8) 50-inch manometer

(9) Two 100-inch manometers

(b) Equipment and Items Needed

(1) Dredge pump, bronze-Plexiglas (see Figure 5).
This is really new case, not a new pump

(2) Accumulator, Plexiglas

(a) Cylinder accumulator (Figure 7)

(b) Vortex accumulator (Figure 6)

(3) Draghead, Plexiglas, (Figure 8)

(4) Four Mechanipak seals with style B ceramic stationary seat and vibration ring B-T996-16, for 2-1/4 inch shaft

(5) Plexiglas tubing for the suction side (Figure 3.).

(a) 1.2 ft. of (5-1/2 in. O.D. and 4-1/2 in. I.D.)

(b) 2.0 ft. of (7 in. O.D. and 6 in. I.D.)

(c) One elbow (5-1/2 in. O.D. and 4-1/2 in. I.D.)

(6) Plexiglas flanges (Figure 5)

(a) Two flanges (7 in. O.D. and 6.0 in. I. D.)

(b) Ten flanges (5-1/2 in. O.D. and 4-1/2 in. I.D.)

(7) Plastic sheets for the suction tank

(a) Two sheets (3/4 by 60 by 72 in)

(8) Steel piping. (Figure 4)

(a) 15 ft. of (6 in. I.D.)

(b) 1 ft. of (4-1/2 in. I.D.)

(c) 13 ft. of (10 in. I.D.)

(d) 1 ft. of (4 in. I.D.)

(9) Steel flanges (Figure 4)

(a) Two 10 in. flanges

(b) Seven 6 in. flanges

(c) Two 4-1/2 in. flanges

(d) Three 4 in. flanges

(10) Steel elbows (Figure 4)

(a) three 6 inch elbows

(b) one 6 by 4 inch elbow

(11) Victaulic couplings (Figure 4)

(a) Two 10 inch couplings

(b) Six 6 inch couplings

(12) Gate valves (Figure 4)

(a) One 6 inch gate valve

(b) One 10 inch gate valve

(13) Structural steel for pump foundation and support

(a) 20 ft. 6 in. channel

(b) 4 ft. 8 in. channel

(c) 10 ft. 6 in. I section

(d) 7 ft. 4 in. I section

(e) 42 ft. (3 by 3 by 1/4 in. angle)

(14) Extension of discharge tank

Plates

(a) One plate (1/4 by 67-3/8 by 48 in.)

(b) One plate (1/4 by 69-1/2 by 48 in.)

(c) One plate (1/4 by 71-1/4 by 48 in.)

Baffles

(a) One baffle (1/4 by 66 by 48 in.)

(b) One baffle (1/4 by 72 by 48 in.)

Angles

(a) 16 ft. angle (2-1/4 by 2-1/4 by 1/4 in.)

(15) Extension of suction tank

Plates

(a) Two plates (18 by 48 by 1/4 in.)

(b) Two plates (18 by 120 by 1/4 in.)

(16) Concrete for pump foundation (Figure 2)

(a) 2.0 cubic yards

(17) Measuring devices

Manometers

(a) Five Meriam Model 10AA25 WM mamometers, 50 in. range, scale A, 303 stainless steel wetted parts, wall mounting.

(b) Five lbs. Meriam Hi-purity mercury, sp. gr. of 13.57, 0-2913

(c) One pt. Meriam D-7878 fluid, sp. gr. of 1.20

(d) Twenty-four Nylo connectors, 268-N, 1/4 in. O.D.

(e) Twelve Nylo elbows, 269-N, 1/4 in. O.D.

(f) Sixteen Nylo tees, 272-N, 1/4 in. O.D.

(g) Sixteen two-way shut-off valves, 31-E

Pressure and vacuum gauges

(a) 100-psi range pressure gauge, cat. no. 1245

(b) 2-30 in. vacuum gauges, cat. no. 1245

Thermometers

(a) 3-0^{o}-100^{o} C range), 24 in. long, M354, thermometer

(18) Carbon dioxide gas and control devices

(a) 600 50-lb cylinders CO_2 gas, welding grade

(b) 1-Air-Co style 8035 stock no. 806-8035 solar heated CO_2 flow-meter type regulator.

(c) 2 measuring devices

(19) High speed motion picture films and processing

(a) 150 Dupont high-speed reversal pan type 931 film and processing

(20) 4 gallons of protective paint

(21) 30 hours of computer time for data processing

(22) Labor for calibration of the flow meter

(23) Labor for electrical installation

(24) Dynalog paper

(25) Vacuum pumps

(a) Single stage rotary vacuum pumps, model 7DB, ~~7.5~~ 15 hp (Allis-Chalmers)

(b) Single stage rotary vacuum pumps, model 5CCA, 3 hp (Allis-Chalmers)

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(1) John B. Herbich
GAS REMOVAL SYSTEMS ASSOCIATED WITH DREDGE PUMPS
Lehigh University, Fritz Engineering Laboratory Report No. 310.1, February 1964

(2) P. A. Vesilind and J. B. Herbich
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(3) John B. Herbich
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(4) John B. Herbich and W. P. Isaacs
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Lehigh University, Fritz Engineering Laboratory Report No. 310.3, June, 1964

A P P E N D I X

(Figures 1-8)

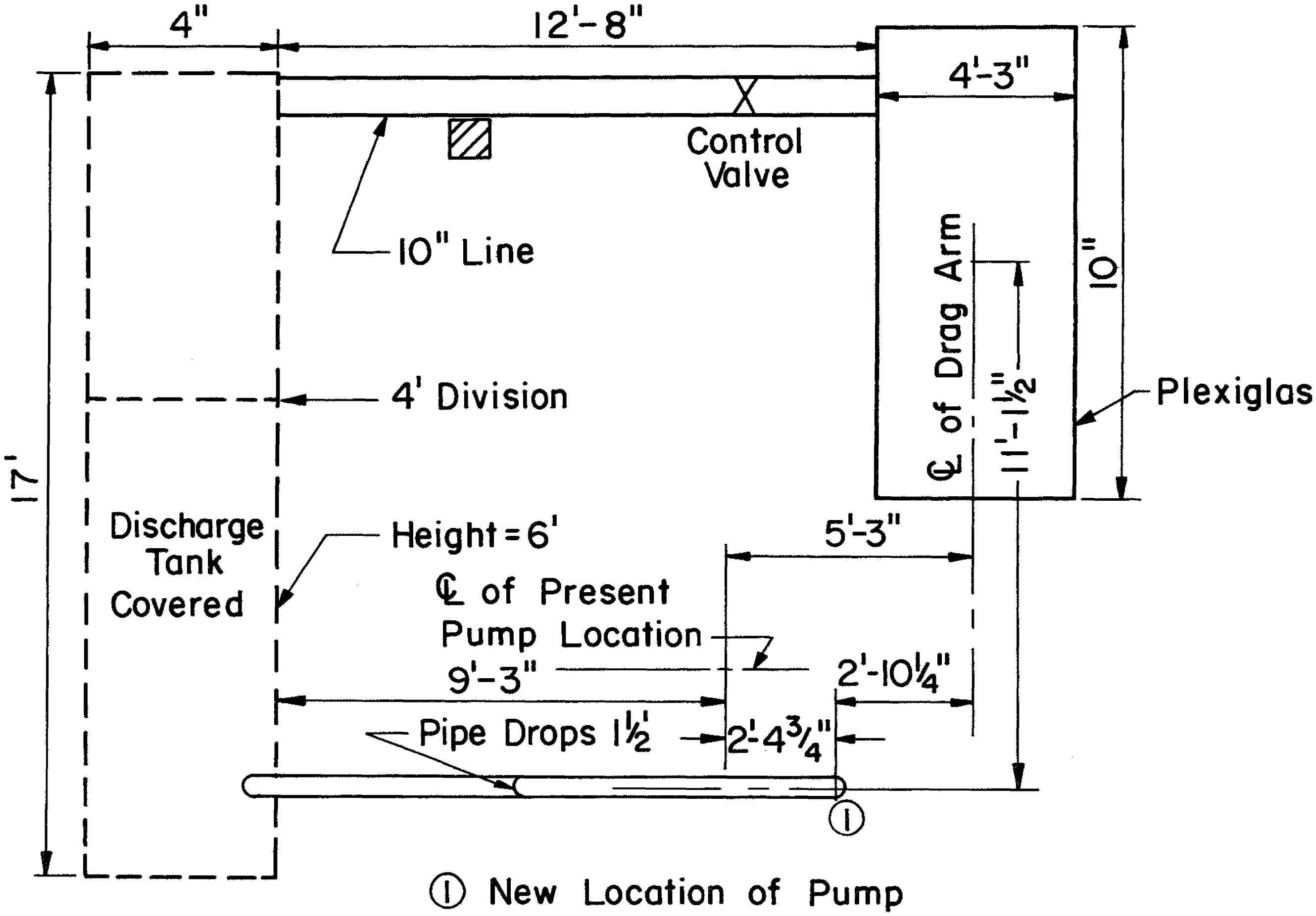


Figure 1. Proposed Floor Plan for Test Facility

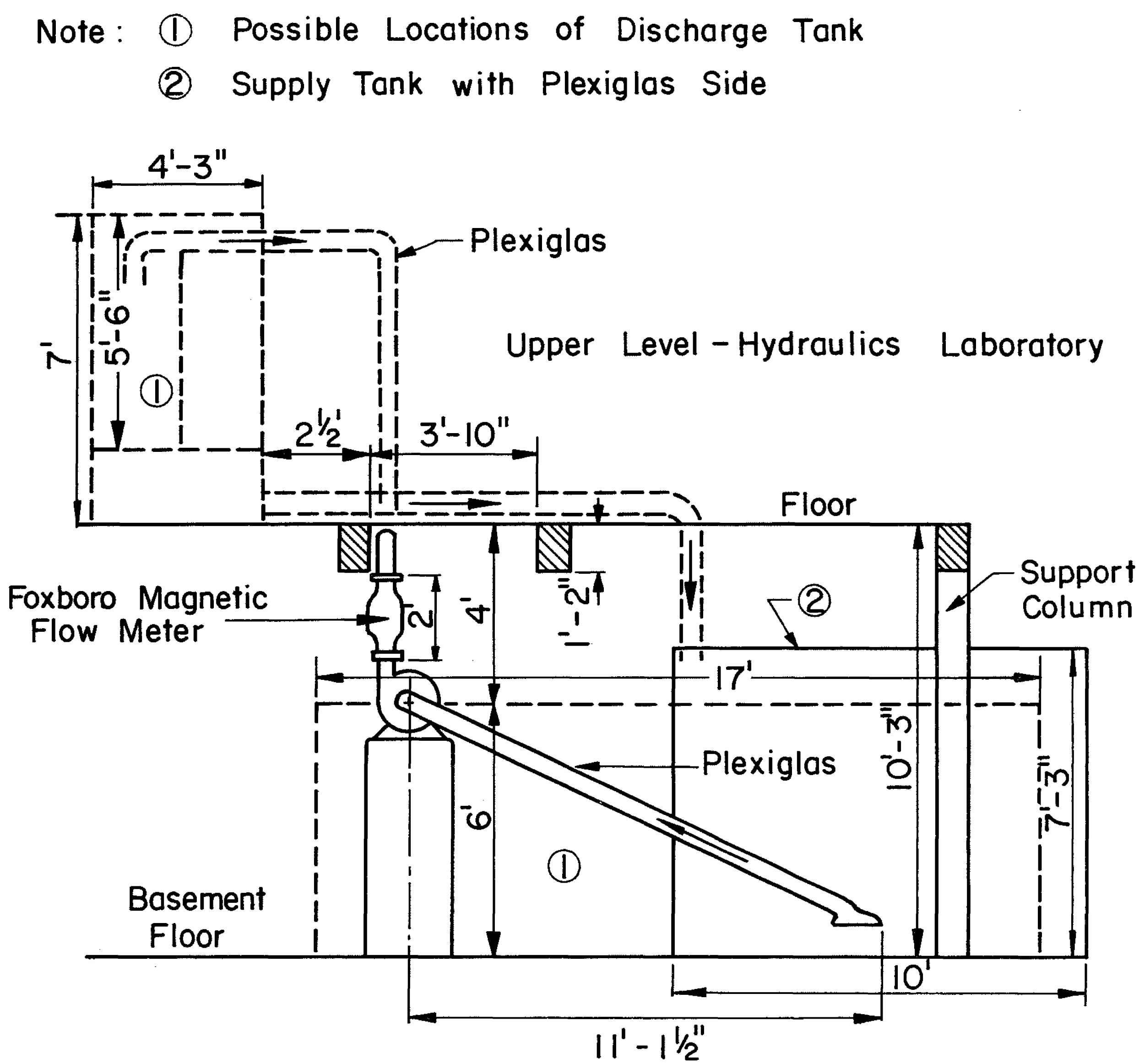


Figure 2. Side Elevation-Proposed Test Facility

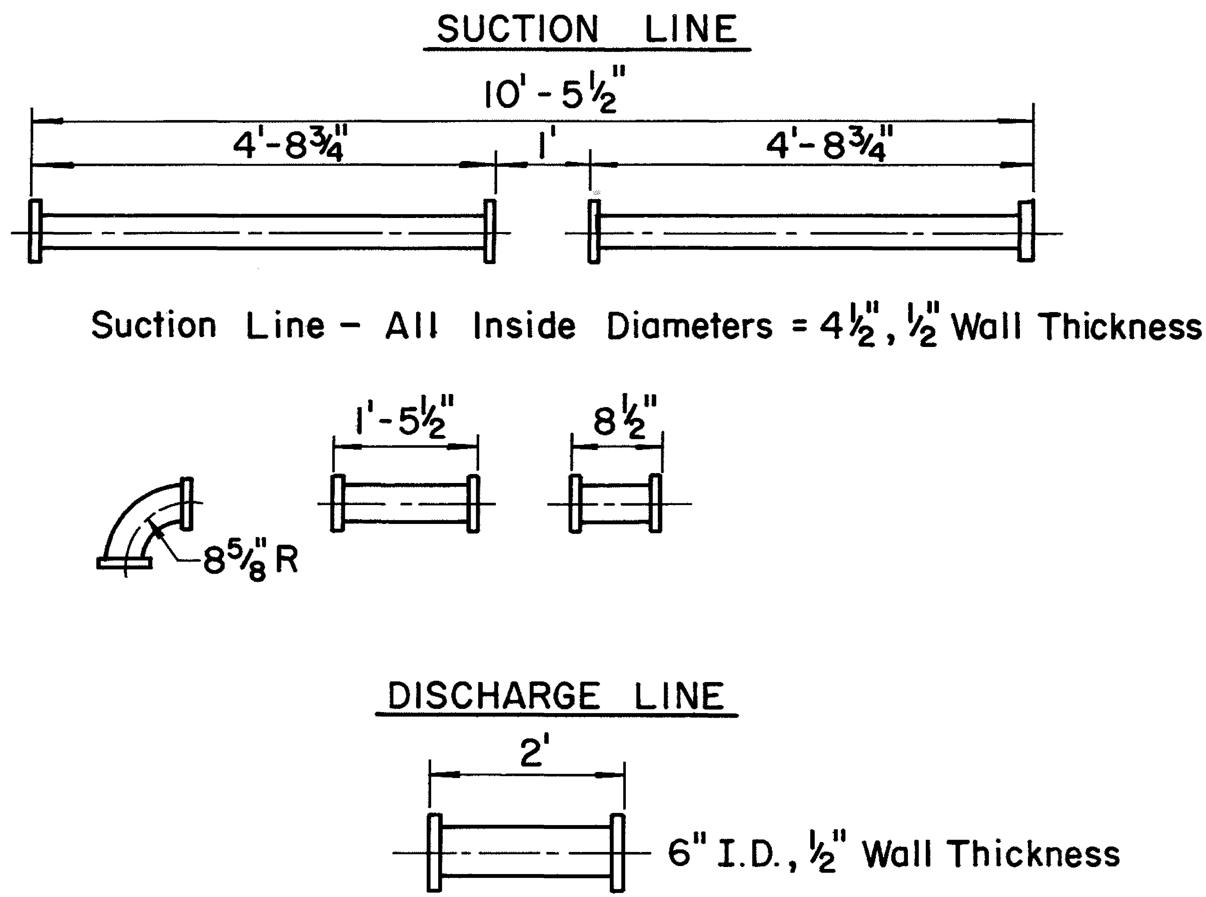


Figure 3. Plexiglas Piping

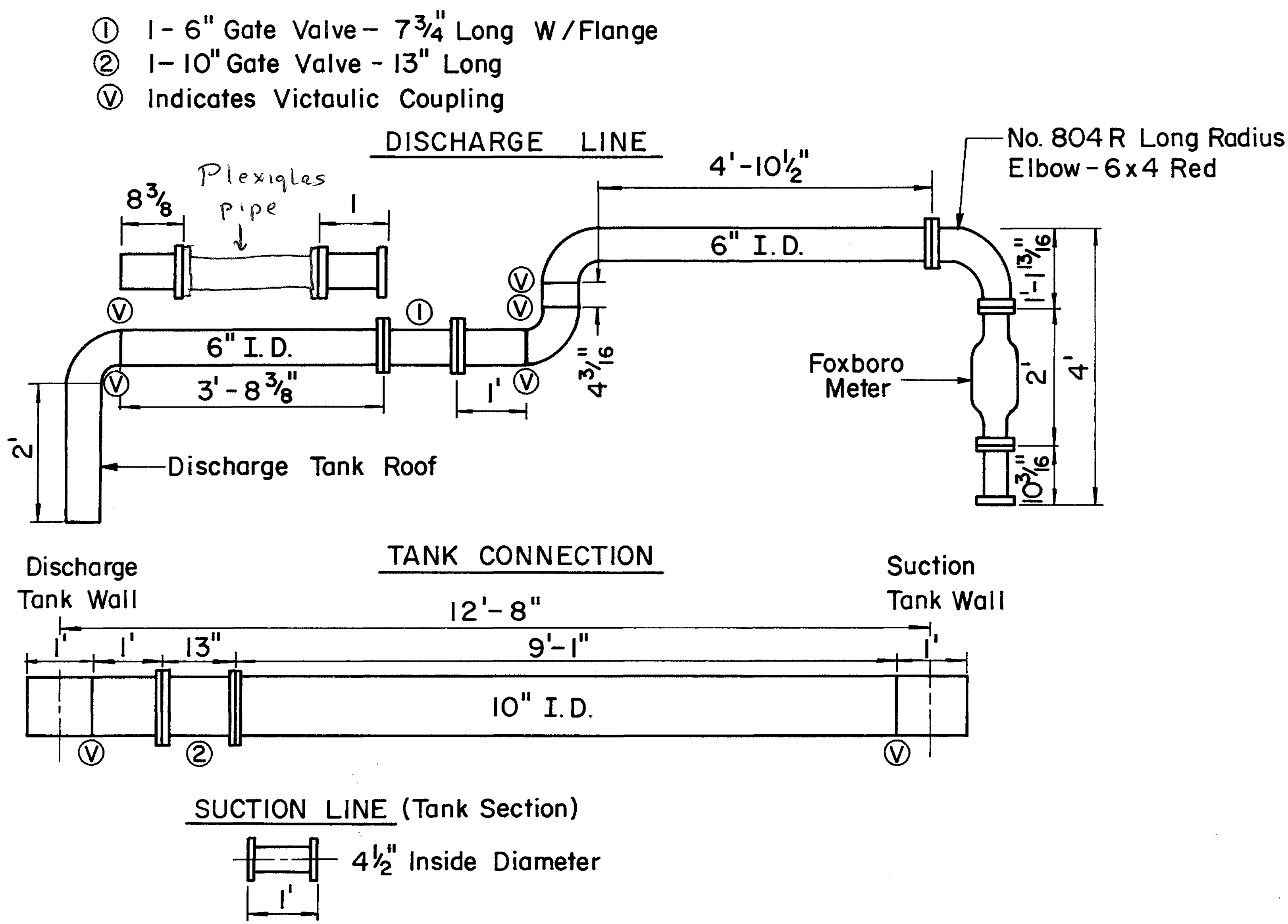
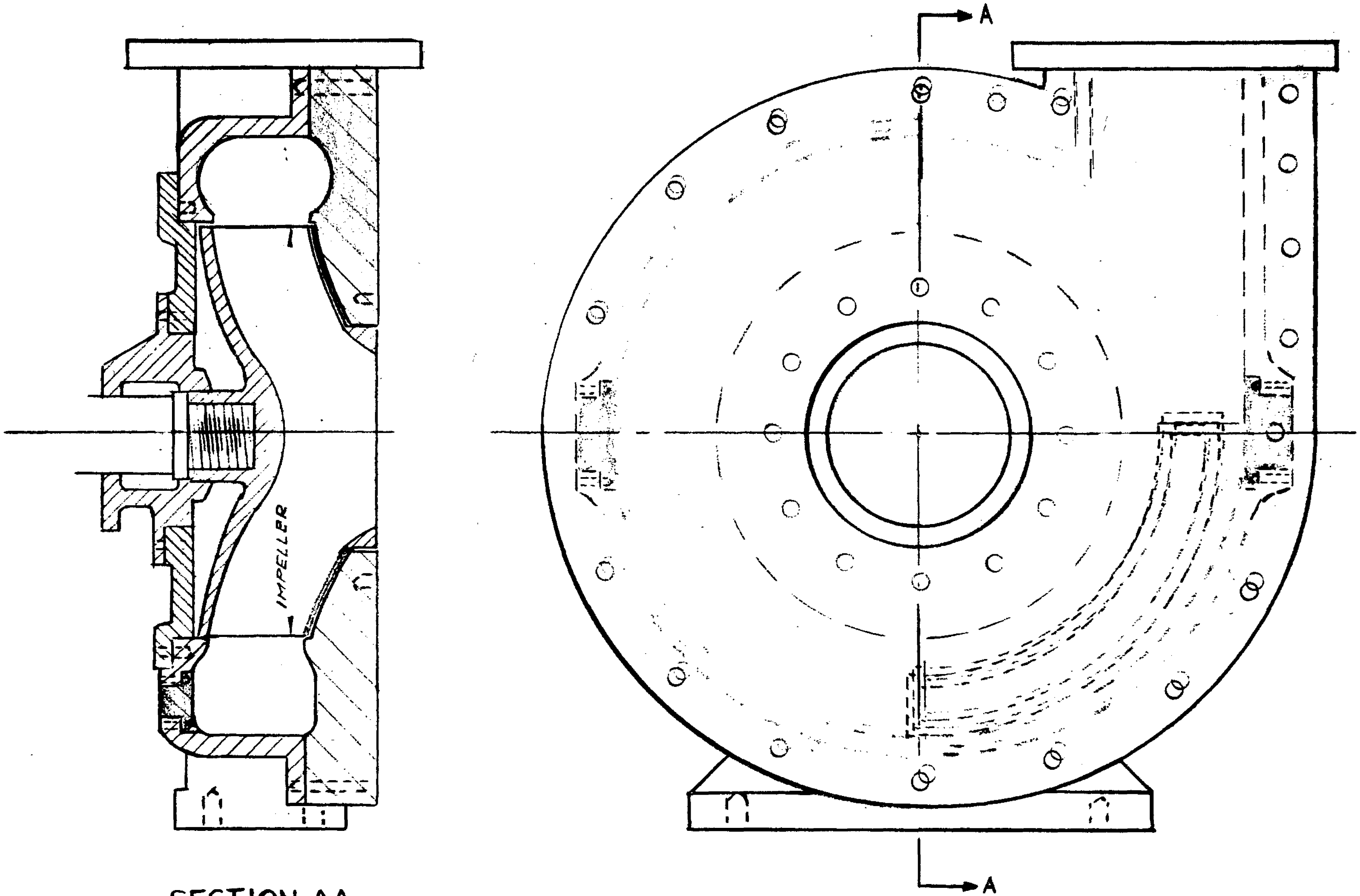


Figure 4. Malleable Iron Piping



SECTION AA

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BRONZE-PLEXIGLASS MODEL PUMP

Figure 5 Drawing 310.10

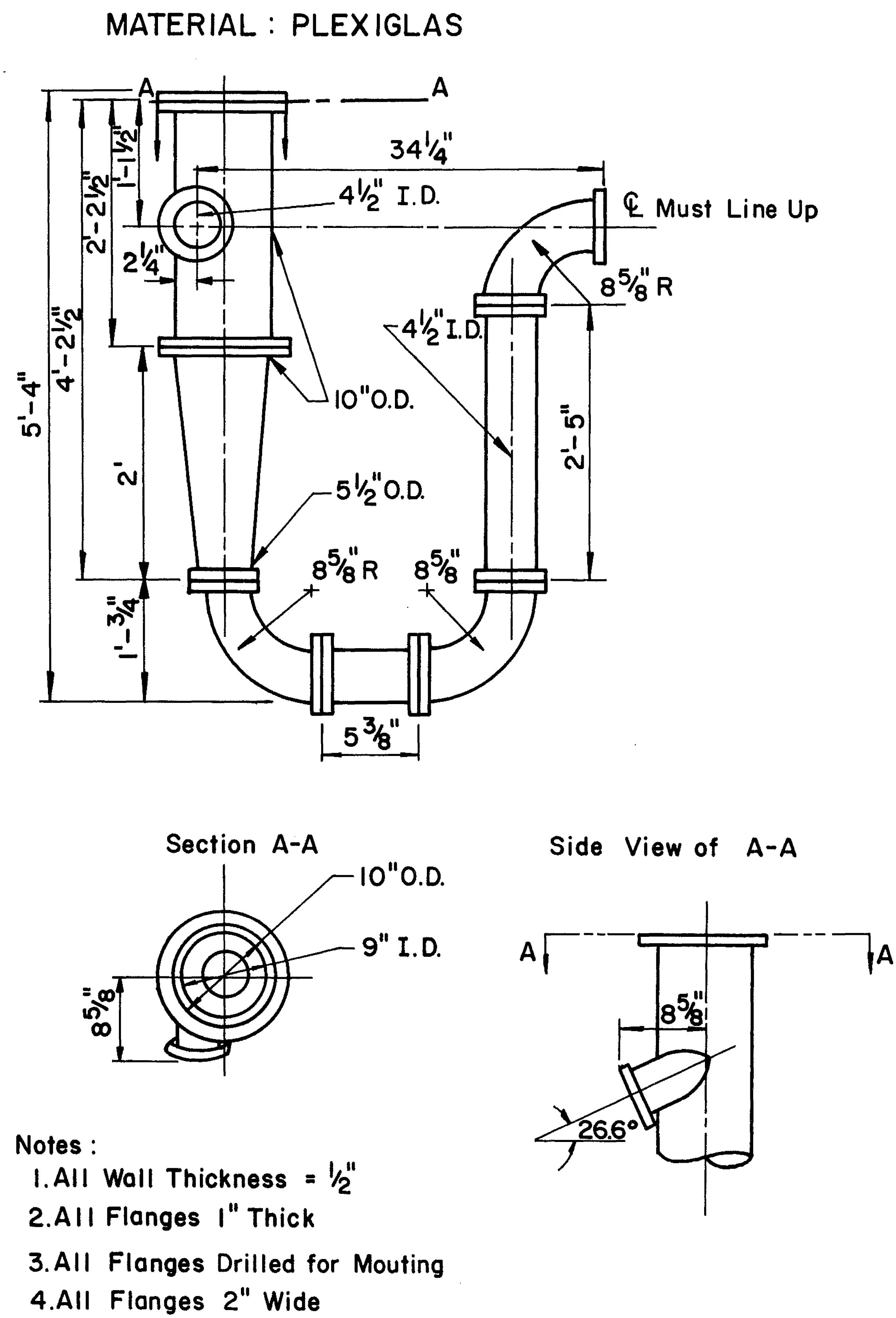

Figure 6. Vortex Accumulator

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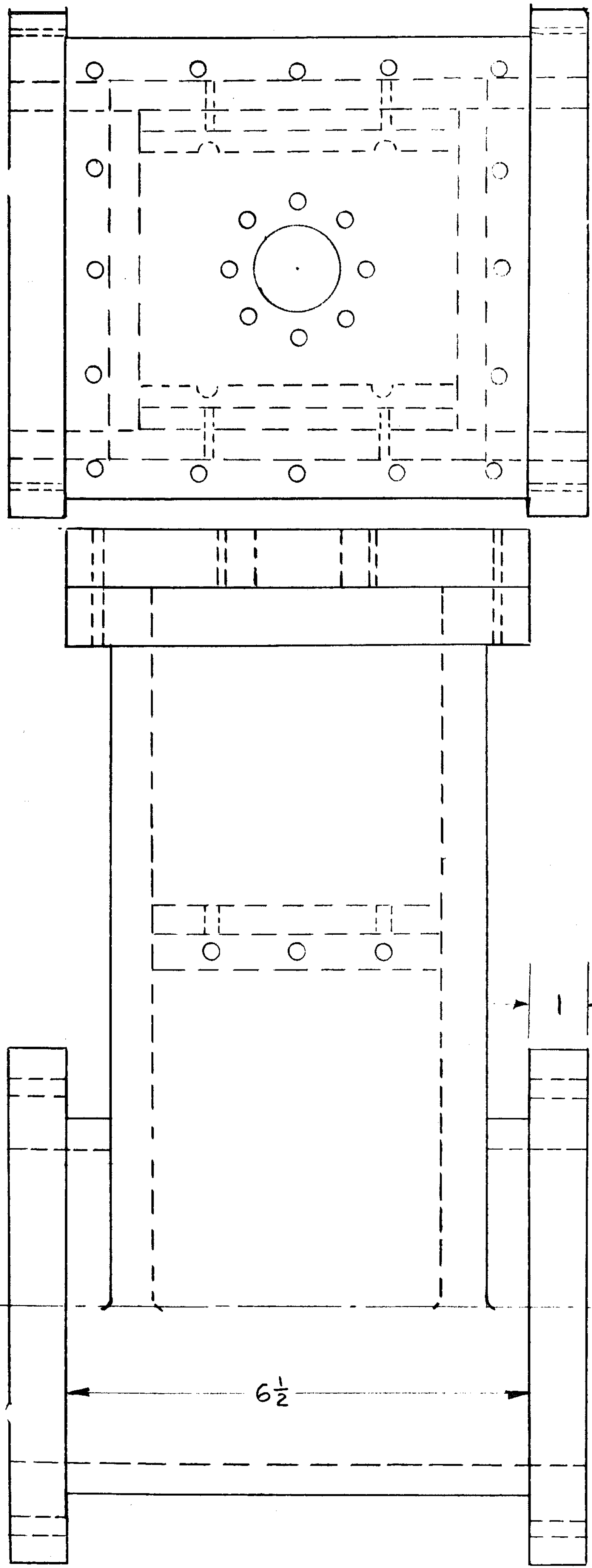
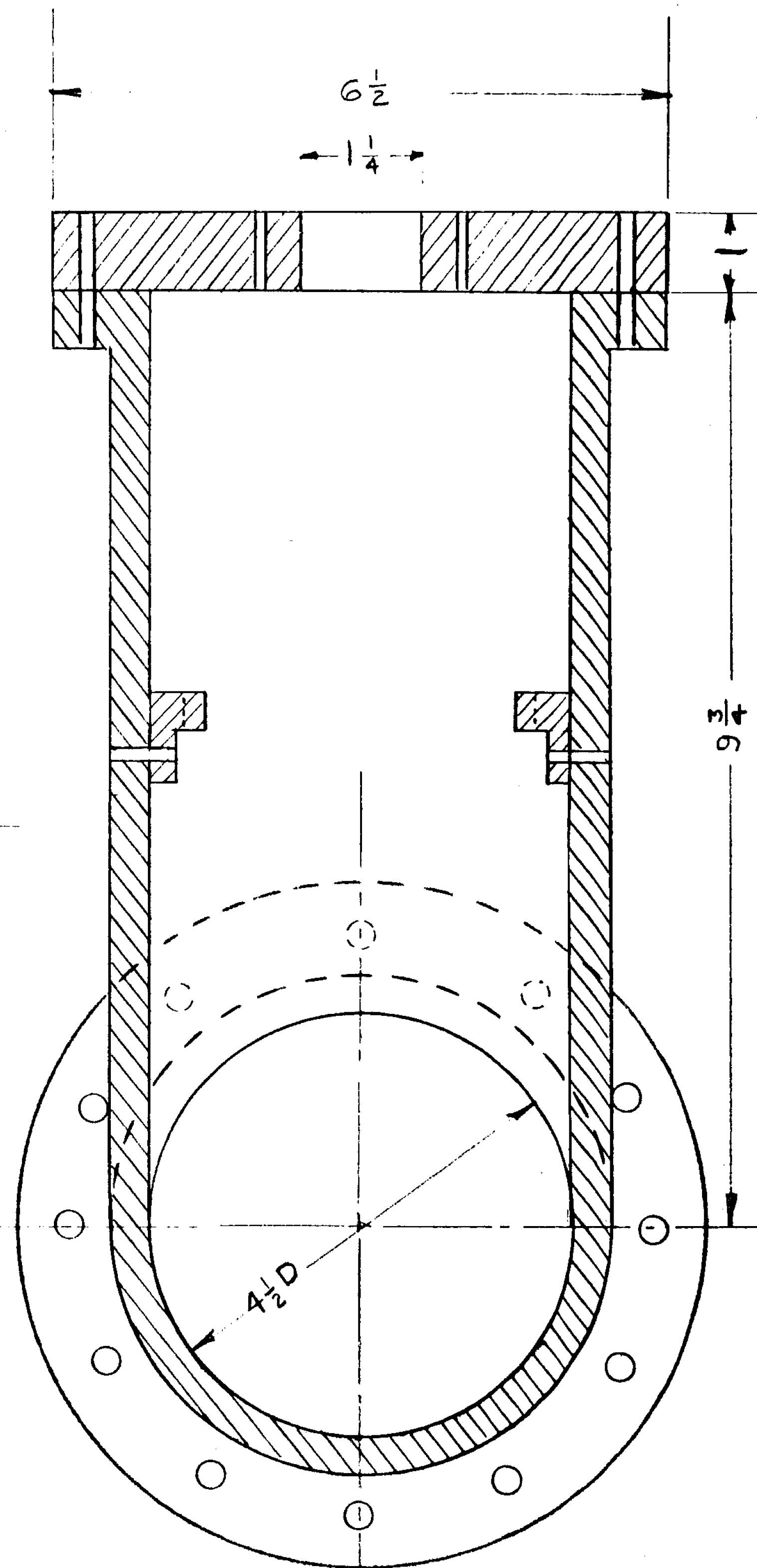
CYLINDER ACCUMULATOR

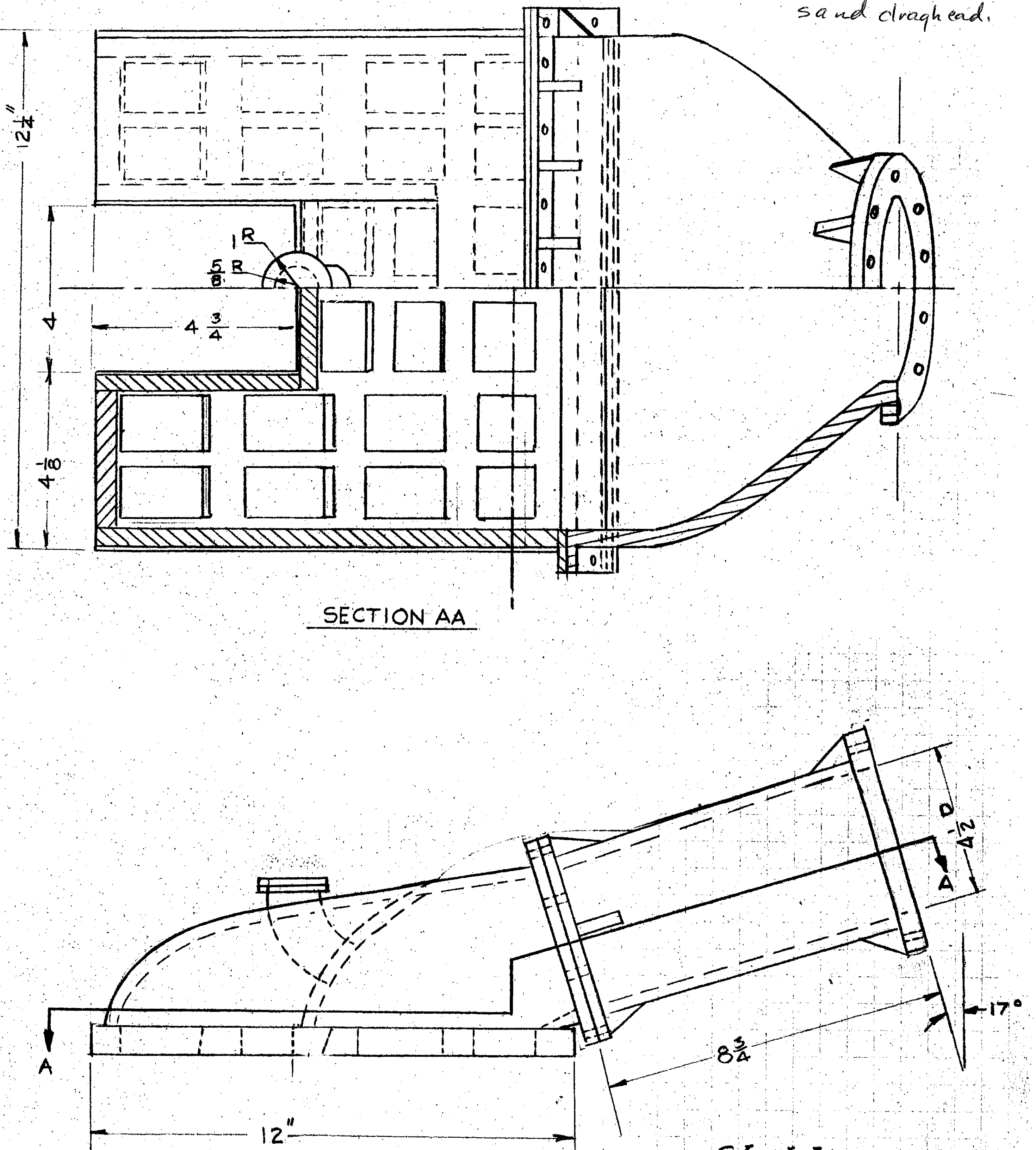
DRAWING 310.3 FIGURE 7

SCALE 1:2 ALL DIM. IN INCHES





This is a sand draghead.



Scale 1" = 3⅓"

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MODEL DRAG HEAD

DRAWING 310.4 FIGURE 8