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Hydrodynamics of Fischer-Tropsch Synthesis in Slurry Bubble Column Reactors

Quarterly Technical Progress Report

for the period 1 September 1984 - 30 November 1984

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I. Abstract

The design basis for the experimental apparatus for measurement of hydrodynamic properties of a high molecular weight paraffin wax has been established, and the flow diagram has been completed. Preliminary detailed drawings of major vessels, and other metal parts have been completed. Purchase orders for some instruments and equipment have been made.

II. Objective and Scope of Work

The overall objective of this contract is to determine effects of reactor geometry, distributor design, operating conditions (i.e., temperature and gas flow rate), and oxygenated compounds on hydrodynamics of slurry bubble column reactors for Fischer-Tropsch synthesis, using a hard paraffin wax as the liquid medium. To accomplish these objectives, the following specific tasks will be undertaken.

Task 1 - Project Work Plan

The objective of this task is to establish a detailed project work plan covering the entire period of performance of the contract, including estimated costs and manhours expended by month for each task.

Task 2 - Bubble Column Reactor Design/Construction

Two bubble columns made of borosilicate glass of approximately 2" ID and 9" ID, and 10 ft tall will be designed, and assembled for measurement of the gas hold-up, and the bubble size distribution. After the design, procurement of equipment and instrumentation, and construction of the unit is completed, a shakedown of test facilities will be made to verify achievement of planned operating conditions. During this period instruments will be calibrated.

Task 3 - Process Variable Studies

The objective of this task is to determine the effect of various system variables (e.g. gas flow rate, temperature, and addition of minor amounts of oxygenated compounds) on hydrodynamic properties using the two-bubble columns (2" and 9" ID) and different types of distributors. All experiments will be conducted using nitrogen at atmospheric pressure. It

is planned to determine the following hydrodynamic characteristics: gas hold-up, flow regime characterization, bubble size distribution, and the gas-liquid interfacial area.

Task 4 - Correlation Development and Data Reduction

Correlations based on our experimental data, for prediction of average gas hold-up, and the gas-liquid interfacial area will be developed.

III. Summary of Progress

- The Project Work Plan (Task 1) has been submitted to the DOE earlier in this quarter
- A flow diagram for bubble columns and the auxilliary equipment has been completed.
- Detailed preliminary drawings for various vessels, bubble column plenum chambers and expansion units have been completed.
- Glass bubble columns were purchased and delivered, and purchase orders have been issued for some instruments and equipment.

IV. Detailed Description of Technical Progress

The bubble column dimensions, and the range of operating conditions that form the design basis are specified in Table 1.

The flow diagram of experimental set-up is shown in Figure 1. Nitrogen gas flow rate will be metered and regulated with a mass flow meter/controller (2" ID bubble column - BC2), and with an orifice type meter with a pneumatic controller and a control valve (9" ID bubble column - BC1). The flow rate for the BC1 will also be monitored with a mass flow meter. The gas will be preheated to a desired temperature by passing it through electrically heated packed bed before it enters one of the two bubble columns. The bubble columns are made of borosilicate glass and have the following dimensions: BC1 - the inside diameter is 229 cm (approximately 9 in) and the total height is 300 cm (two sections of 150 cm each); BC2 - the inside diameter is 5.1 cm (2 in), and the total height is 305 cm (two sections of 5 ft each). The columns will be electrically heated, and their temperature will be regulated by temperature controllers. They will be covered with an insulating fiber type of material, which can be removed at desired locations for the purpose of visual observations, and/or photographic measurements. Each column has an expansion unit at the top to reduce entrainment of the liquid from the column. The gas and the entrained liquid which leave the column pass through a gas-liquid separator -2, and any liquid collected in the separator is either recycled to the bubble column or it is sent to a liquid storage tank - 1. All lines beyond the preheater (PH) are electrically heated to prevent solidification of the wax which would cause plugging of the lines.

The liquid (molten paraffin wax designated FT-300) will be fed into the columns from the storage tank - 1 using the nitrogen overpressure. The columns will be emptied through lines at the bottom, and the wax will be collected in the storage tank.

For each bubble column there will be two glass-metal connections: at the distributor level, and at the top (column-expansion unit connection). Different types of gasket materials (e.g. teflon, ceramic paper, glass fiber) will be tested for the purpose of finding the material which seals effectively at high temperatures over a long period of time.

The detailed drawings of expansion units for the two bubble columns are given in Figures 2 and 3. Dimensions of the plenum chambers are shown in Figures 4 and 5, and of the gas-liquid separator and the storage tank in Figures 6 and 7 respectively. The column support structure is shown in Figure 8. All dimensions shown in these Figures are preliminary as we shall continue to seek improvements in our design. These metal vessels will be made in our machine shop according to our final specifications.

The instruments for temperature measurement, indication and control, the mass flow controller for the 2" ID bubble column (Brooks-Instruments, Model 5815), the electrical heating tapes, and the insulation material for the unit have been ordered. The glass columns have been delivered.

V. Future Work

We plan to order the remaining instruments, tubings, fittings, valves, and the material for the auxiliary vessels, distributors and the expansion units. Fabrication of metal parts will be completed, and the assembly of the entire unit will be initiated.

VI. Table

TABLE 1

BUBBLE COLUMN DIMENSIONS AND EXPERIMENTAL CONDITIONS

• Column dimensions	BC2	BC1
Diameter, cm	5.1	22.9
Height, cm	305	300
• Gas Distributor	15-60 μm Sintered Plate 3-5 mm Single Orifice	Multiple Orifice Multiple Nozzle Manifolds
• Gas	Nitrogen	Nitrogen
• Liquid	FT-300	FT-300
• Variables		
Pressure, atm	1	1
Temperature, °C	230-280	230-280
Superficial Gas Velocity, cm/s	0-10	0-10
Oxygenated Compounds	Will be selected later	

VII. Figures

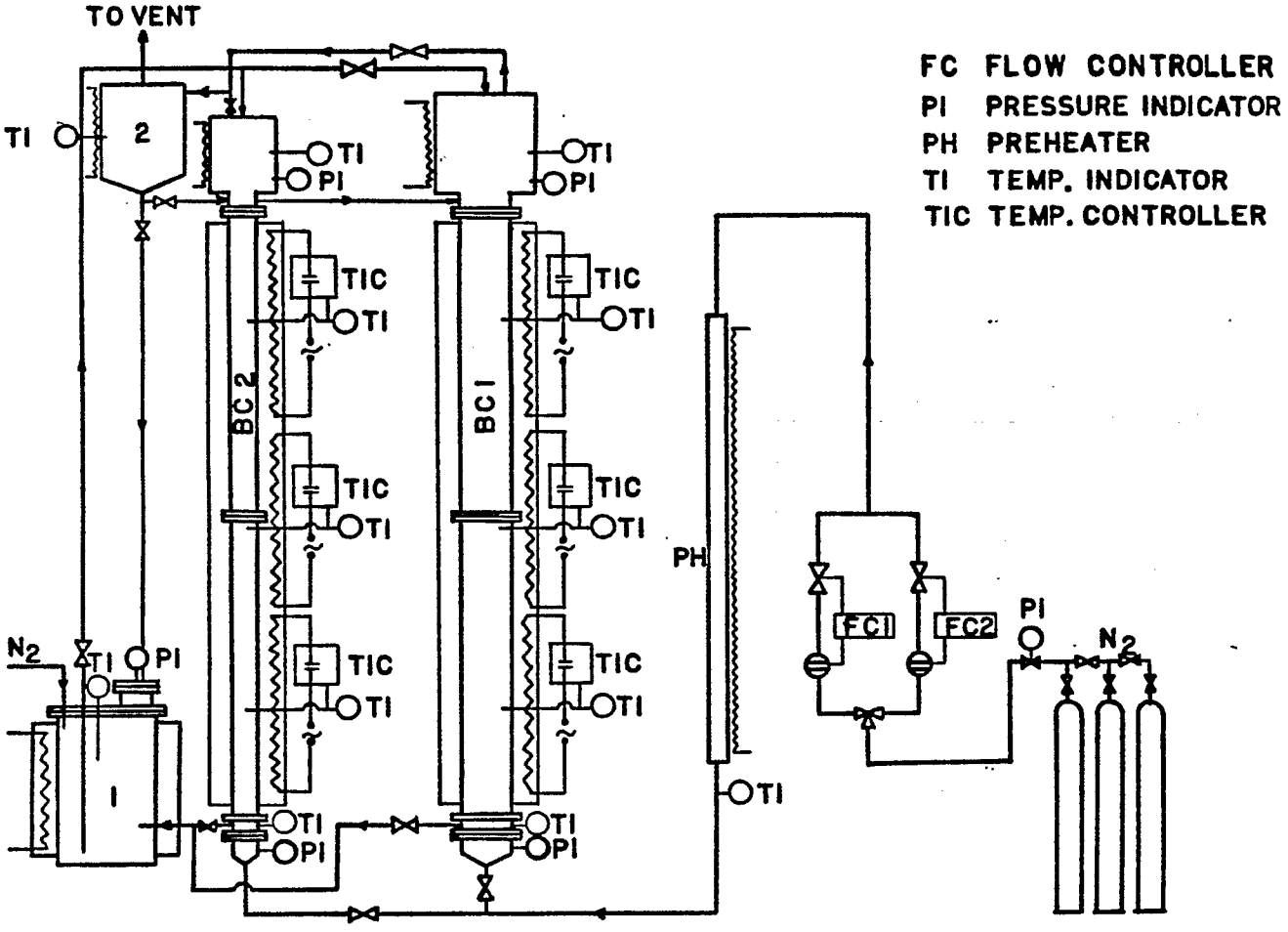

Figure 1. Flow diagram of experimental apparatus

Legend: 1 - Storage tank; 2 - Gas-liquid separator; BC1 - Bubble column (I.D. = 22.9 cm); BC2 - Bubble column (ID = 5.1 cm).

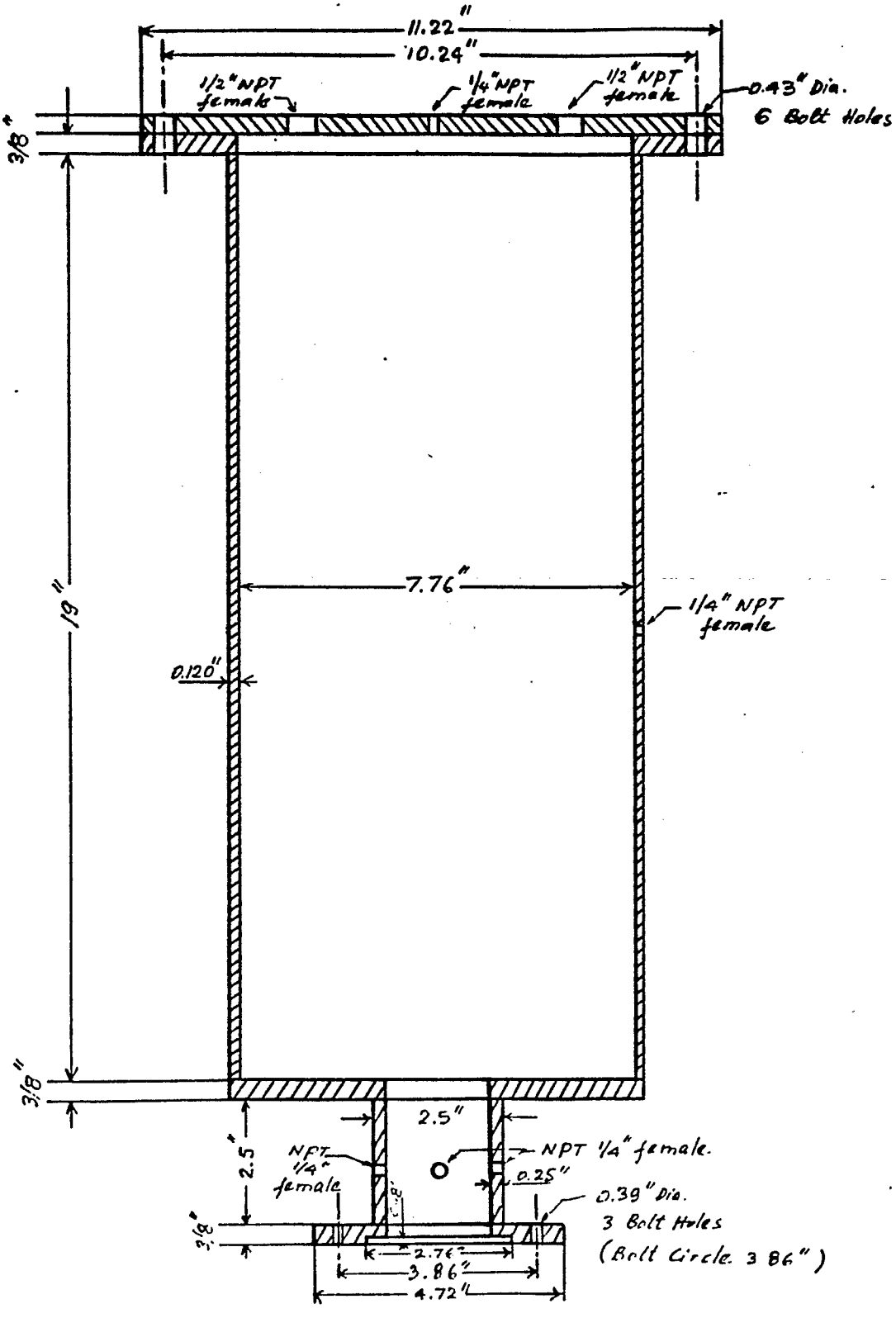

Figure 2: Expansion unit for the 2" ID bubble column (BC2)

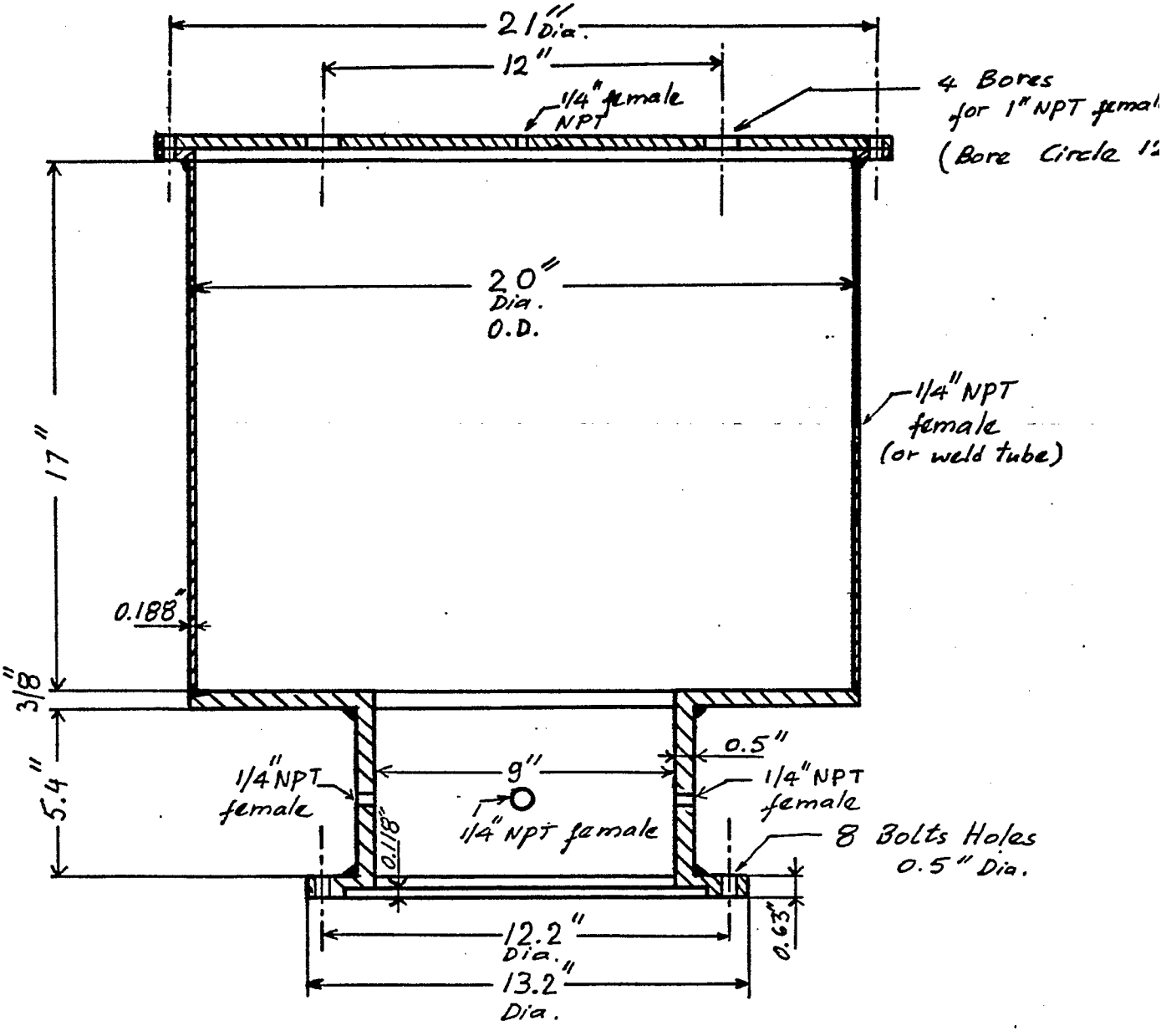

Figure 3: Expansion unit for the 9" ID bubble column (BC1)

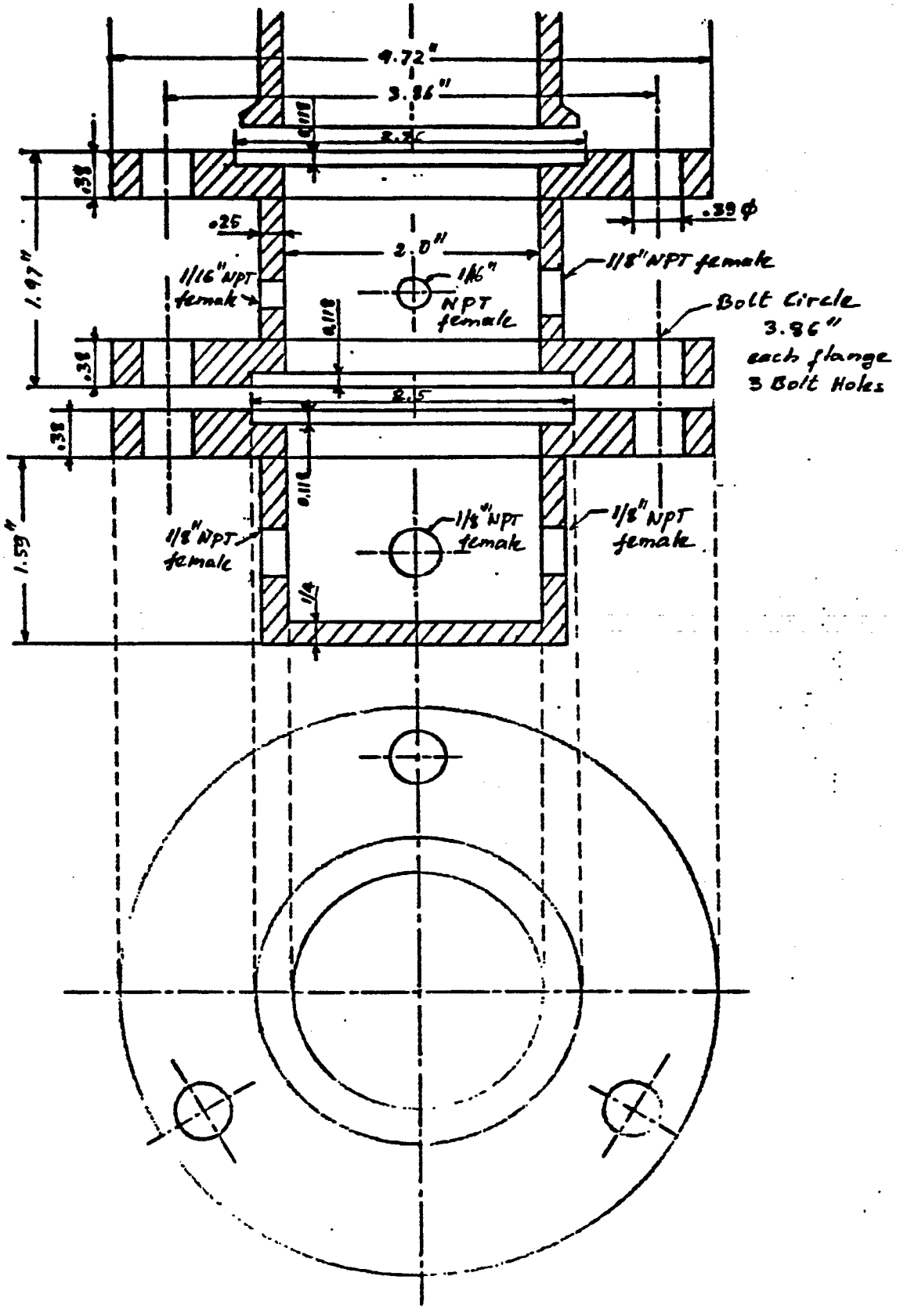

Figure 4: Support and distributor for the BC2

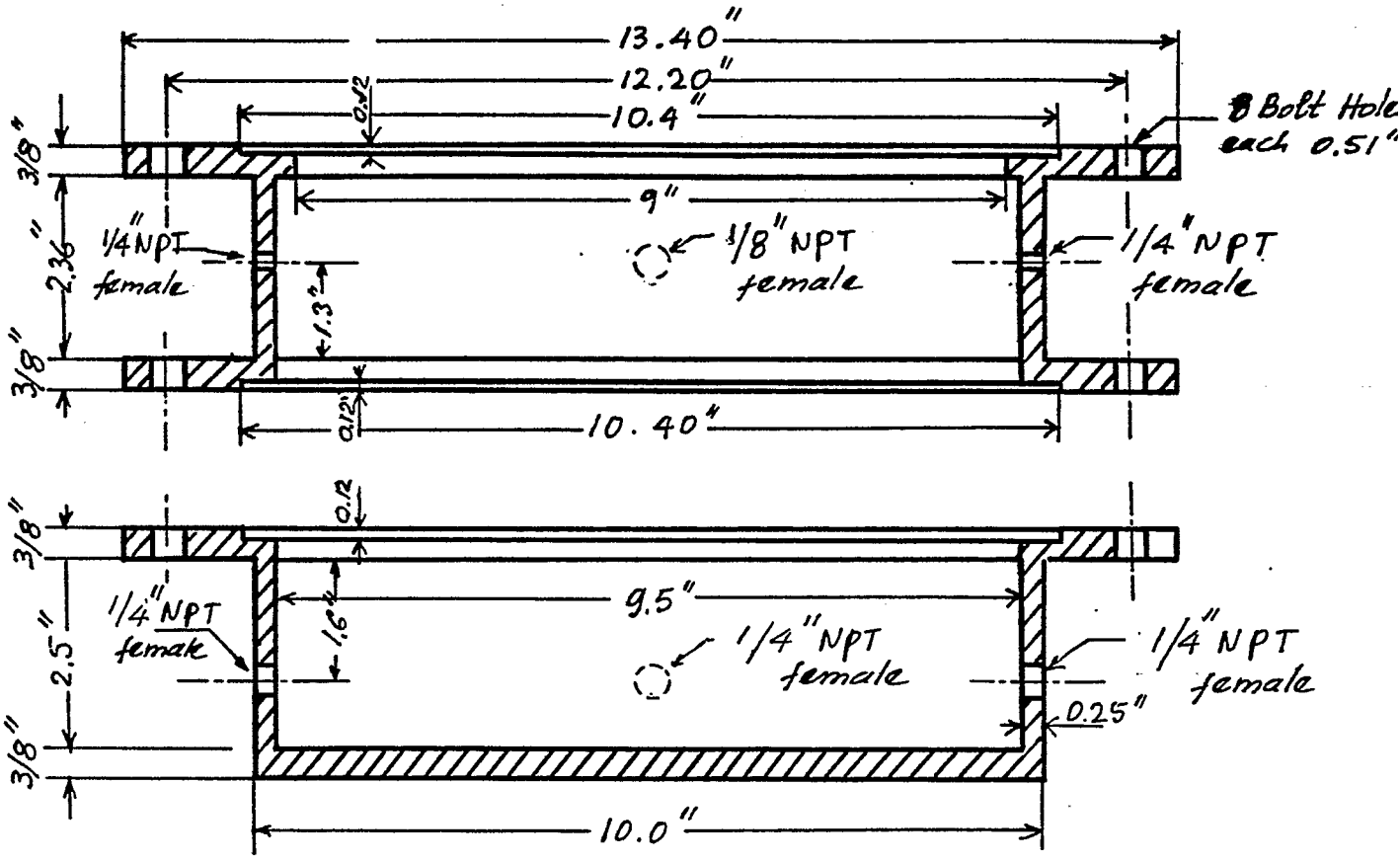

Figure 5. Support and distributor for the BC1

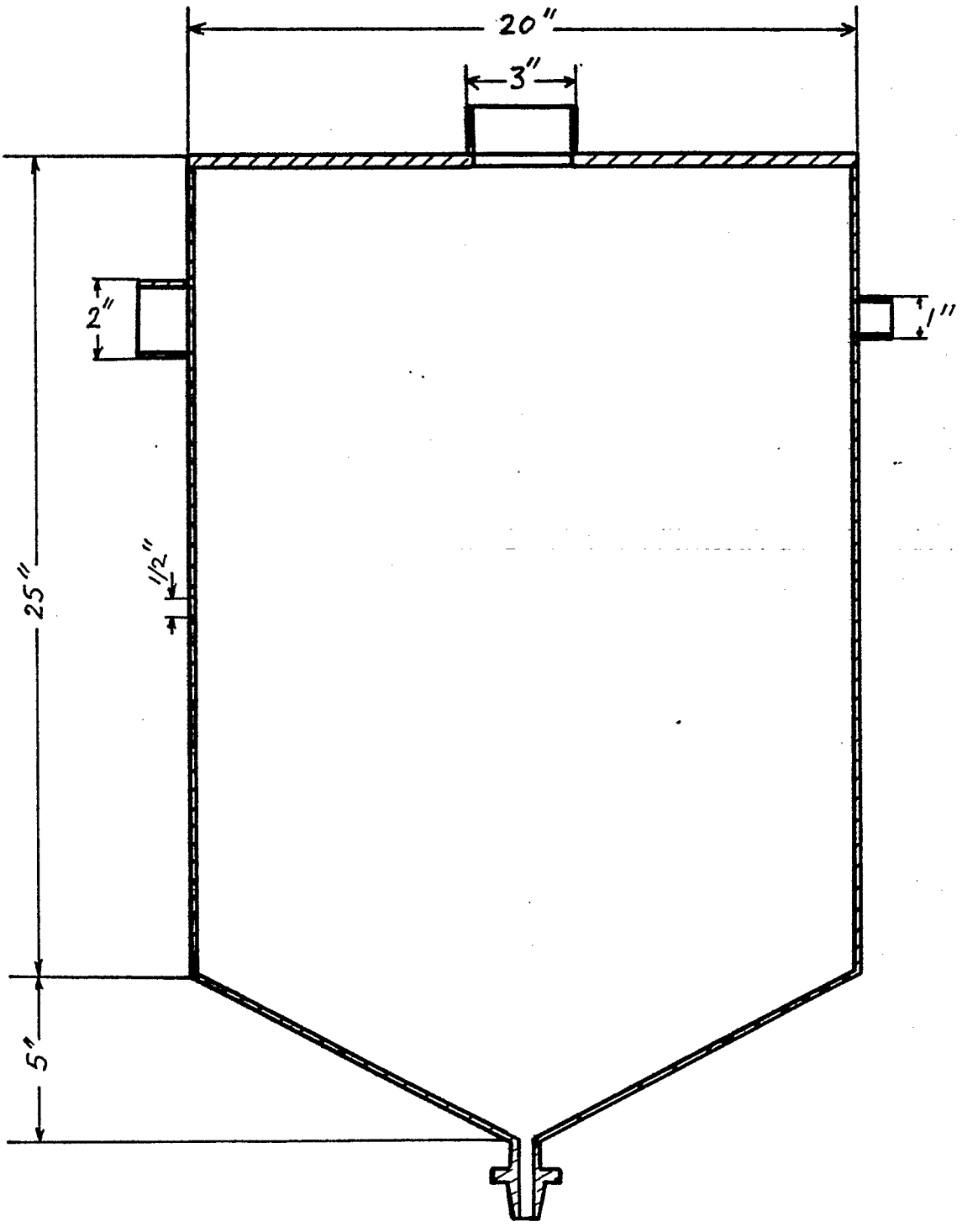

Figure 6. Gas/liquid separator

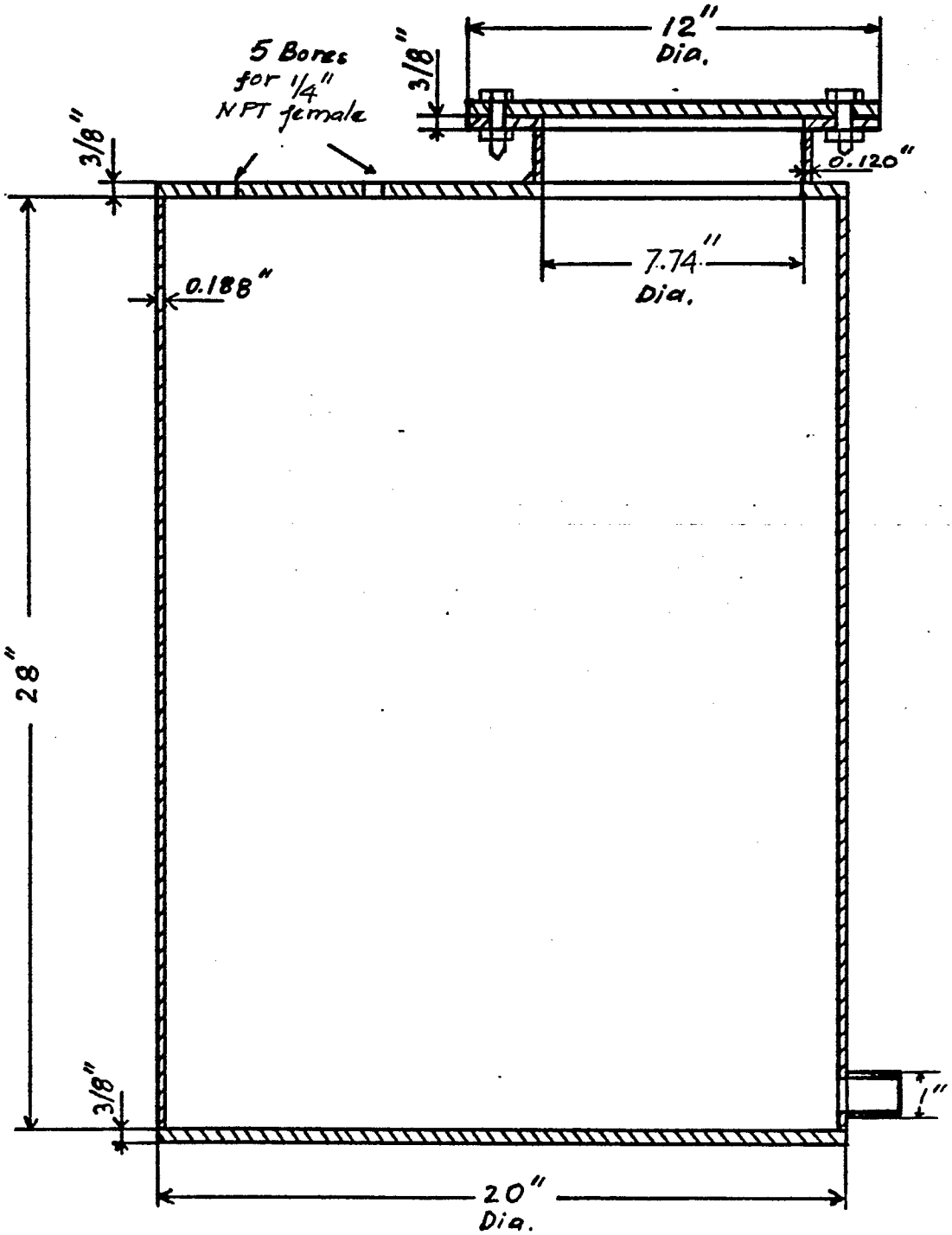

Figure 7: Storage tank for wax

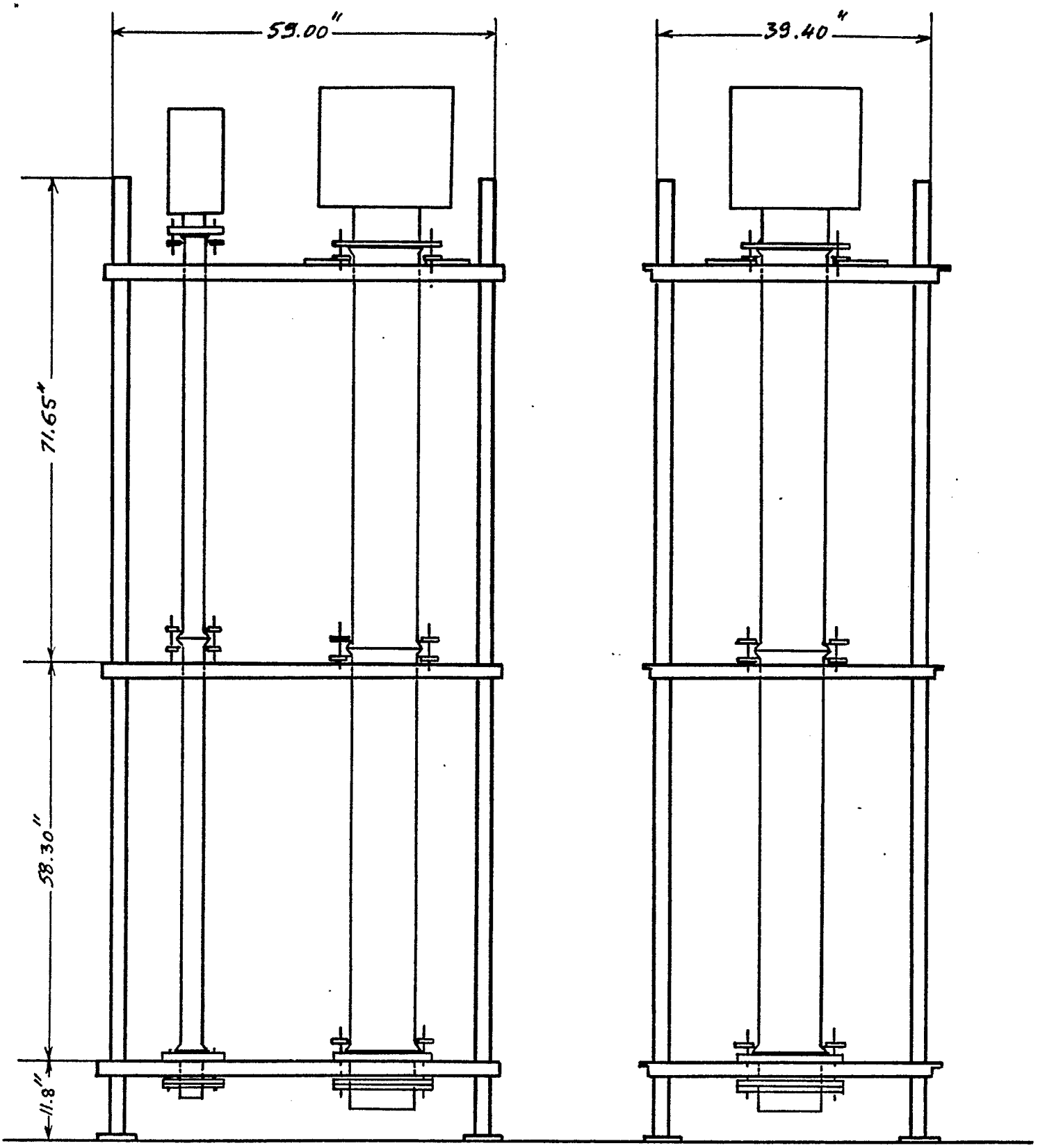

Figure 8: Frame support structure for bubble columns