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HEAT TRANSFER INVESTIGATIONS IN A SLURRY BUBBLE COLUMN: QUARTERLY REPORT FOR THE PERIOD SEPTEMBER--NOVEMBER, 1986

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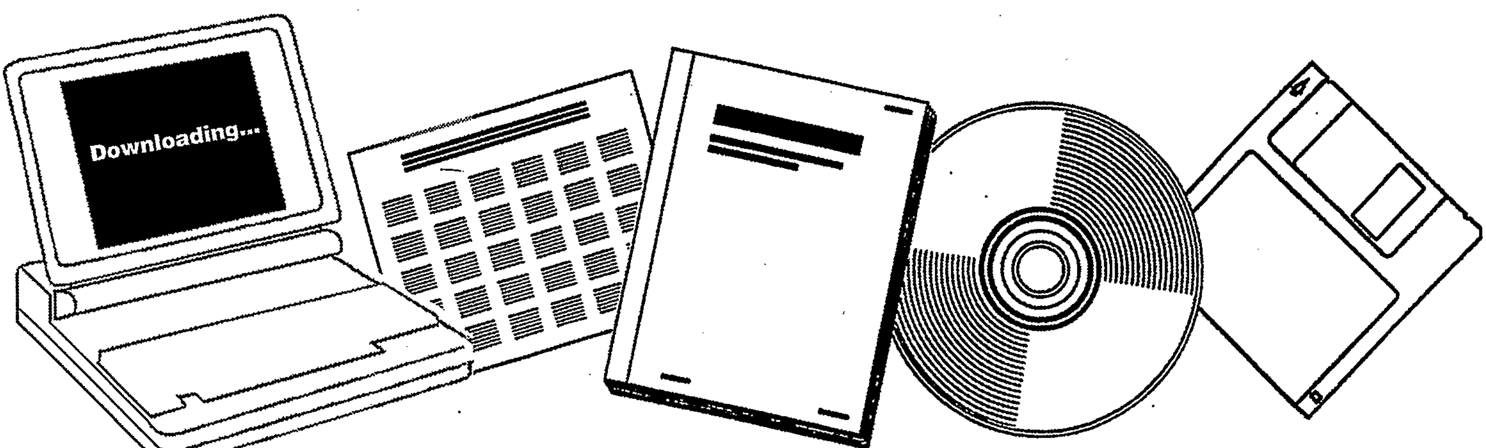

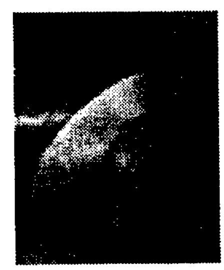

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HEAT TRANSFER INVESTIGATIONS IN A SLURRY BUBBLE COLUMN

Quarterly Report for the Period September-November, 1986

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OBJECTIVES

To investigate the heat transfer characteristics in two slurry bubble columns (10.8 cm and 30.5 cm) as a function of system and operating parameters.

SUMMARY PROGRESS TO DATE

The initial design of the 10.8 cm internal diameter Plexiglas slurry bubble column as well as of the associated gas and slurry flow loops with temperature and pressure measuring devices is completed, and order for most of the required materials is placed. The design of the heat transfer probes is developed and all the basic components have been ordered. These designs are briefly described in this report. The fabrication of the column and of the auxiliary units is in progress and installation of the column will soon start. Dr. Revankar has joined the project on November 3, 1986, and the design work for the bigger 30.5 cm diameter pyrex glass slurry bubble column is being initiated.

DESCRIPTION OF TECHNICAL PROGRESS

The major effort of this contract is experimental in nature and heat transfer phenomenon between immersed surfaces and the slurry phase of the bubble column will be investigated to understand its dependence on geometrical and operating system parameters. To accomplish this, it is planned to install two slurry bubble columns and generate heat transfer data for single probes and probe bundles of different size and configuration in slurries of different properties and at ambient and high temperatures. Slurries will be prepared with liquids of different properties and solids of different sizes (0 - 100 µm), and of different concentrations (0 - 30 weight percent). Air and slurry velocities will be varied between 0 - 30 cm/s and 0 - 1 cm/s repectively. The slurry temperature will be varied from ambient to 550K. During the tenure of two months of this contract a 10.8 cm diameter Plexiglas slurry bubble column has been designed and mostly fabricated. It is being installed and will be operated at room temperature for different slurry concentrations and velocities. In each case a range of air velocities will be employed. The slurry phase temperature will be measured at various radial positions at five different axial heights. Pressure probes are installed at ten different axial positions along the column and these readings will enable to establish the gas holdup in the slurry phase and its variation with height above the gas distributor plate. In the following, this experimental facility consisting of the following independent units is described. The schematic of the slurry bubble column with its associated measurement and supply loops is shown in Figure 1. This test unit is now described under different measurement systems.

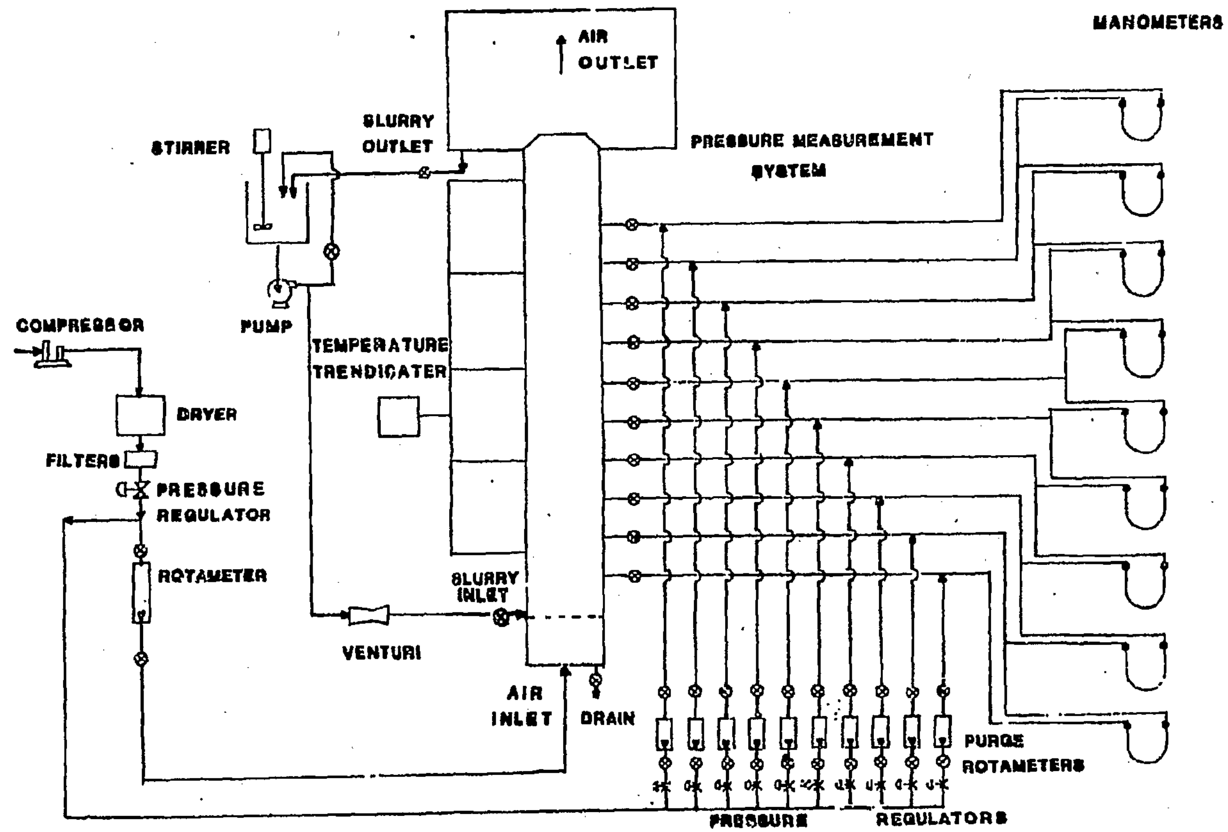


Figure 1. Schematic of The Slurry Bubble Column showing the Air Supply Loop, Temperature and Pressure Measuring Circuits.

The Air Supply System

The air is supplied to the bubble column by a 18.65 kW, two-cylinder, two-stage air cooled Curtis compressor. It is capable of delivering a maximum of 3.0 SCMM of air at 248kPa. The compressed air passes through a 1.65 m^3 surge tank and is dried in an Arrow Pneumatic Inc., refrigeration dryer to a dew point temperature of 275K. The dried compressed air then passes through a cyclone type oil filter and an Oileser cartridge type filter. These remove bulk of the oil vapors and any traces still remaining in the air are finally removed in an activated charcoal filter. This processed air then flows through a pressure regulator and a Fisher-Porter rotameter with a maximum capacity of 0.18 SCMM where its pressure and flow rate are adjusted at the desired levels and metered. An iron-constantan (J-type) thermocouple connected to an Omega Trendicator model 415A is used to measure the air temperature entering into the bubble column. The trendicator converts the input analog signal from the thermocouple to a digital signal in μV by an A/D convertor. The digital linearization and dual slope integration are done by PMOS integrated circuits on the basis of thermocouple tables. The trendicator finally displays the temperature in ^{0}C with a resolution of 0.1^{0}.

The Slurry Bubble Column

The processed air at known temperature, pressure and flow rate enters at the bottom of the slurry bubble column whose engineering design is shown in Figure 2. This column is constructed from a 1.27 cm thick transparent Plexiglas tube having an internal diameter of 10.8 cm. The total height of the column is 225.43 cm and it comprises of a calming section, a test section and an air disengagement section. These three sections are of the nominal heights of 14.61, 170.18 and 40.64 cm respectively. The transparent nature of the column walls will allow easy visual observations and photo-recording of the bed activity. The air enters the bottom of the calming section bubble cap air distributor aluminium plate through a 0.86cm orifice as shown in Figure 3A. The distributor plate is 1.9 cm thick and 7.62 cm in diameter. Two perpendicular cylindrical channels of 0.64 cm diameter are drilled through it and their ends are subsequently plugged. At the top end of this plate five bubble caps are fitted at symmetrical positions as displayed in Figure 3A. The design details of the bubble caps are also given in this figure. Specifically a bubble cap is fabricated from an appropriate size hexagonal cap steel screw. Three equally spaced 2 mm diameter holes with an angular separation of 120^{0} are drilled into the base of the cap at a 45^{0} angle and a 4 mm diameter hole is drilled axially along the length of the screw. The top cap of the screw prevents solids from plugging the 2 mm holes which may have leaked through the air distributor plate. This calming section arranges the air for a uniform flow through the distributor plate at its top end. The design details of the air distributor plate assembly are shown in Figure 3B.

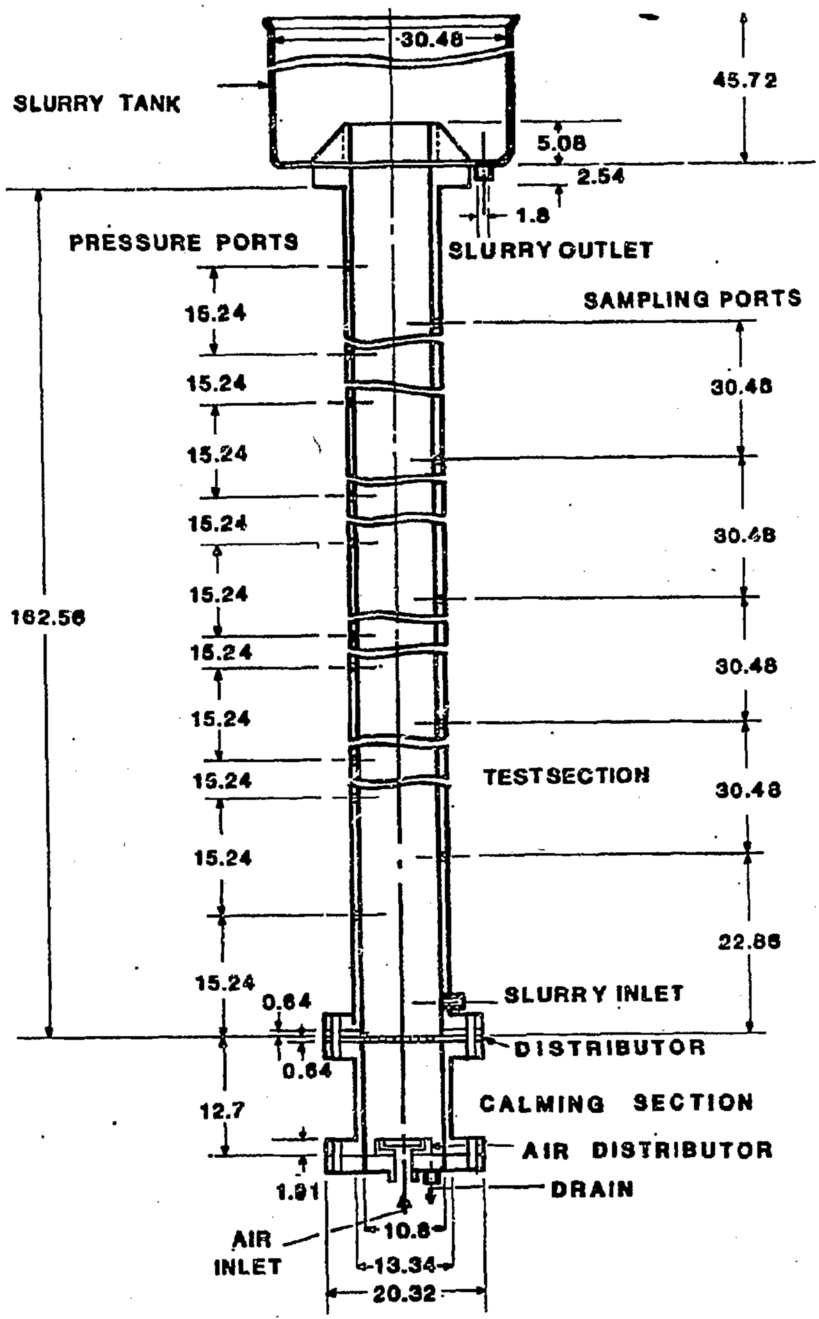
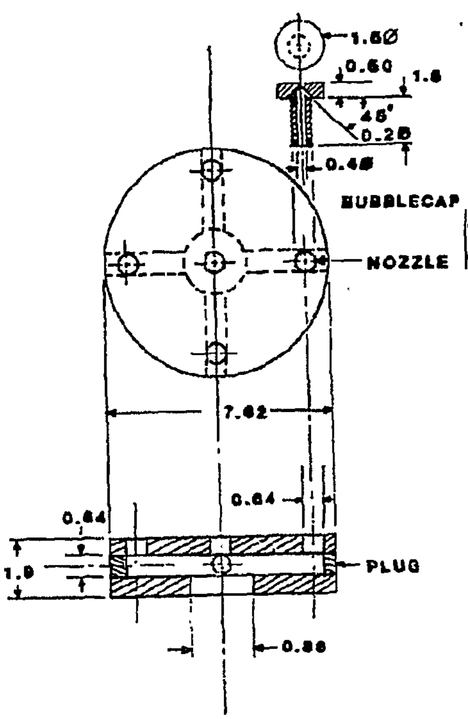


Figure 2. Engineering Design Diagram of the Three-Phase Bubble Column. All Dimensions are in cm.



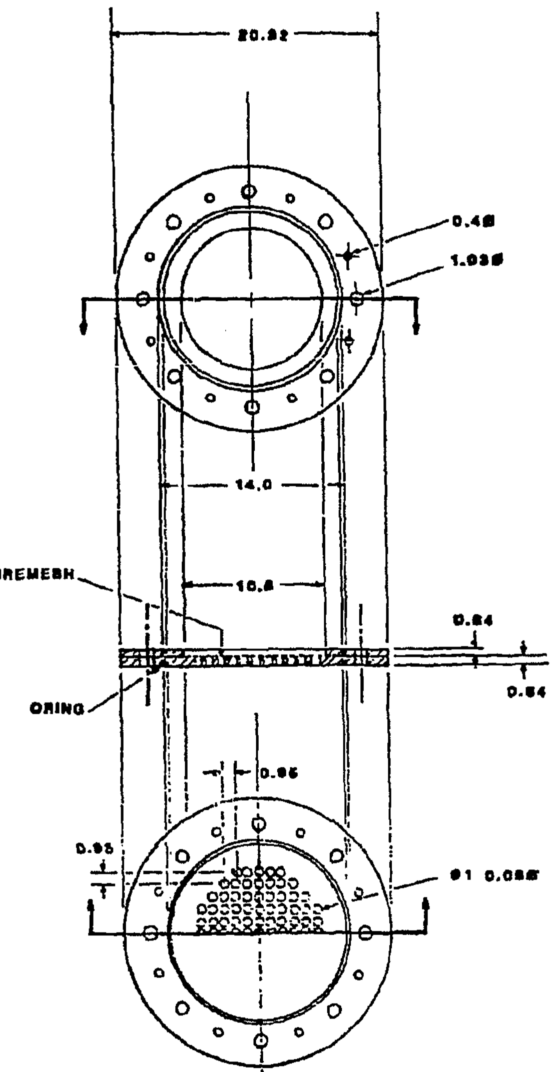


Figure 3A. Details of the Bubble Cap Air Distributor Plate for the Calming Section. All Dimensions are in cm.

Figure 3B. Design Details of The Air Distributor Plate for the Slurry Bubble Column. All Dimensions are in cm.

It consists of a 6.4 mm thick Plexiglas plate with 91 holes of 0.8 mm diameter arranged in an equilateral triangular pitch. To prevent solids weeping into the calming section a wire mesh screen is installed through an O-ring flange assembly. This section communicates with the main test section through another O-ring flange joint as shown in Figure 2. The test section has a 1.27 cm internal diameter inlet for slurry at the bottom. Ten ports of 0.64 cm for pressure measurement are provided along the column height at equal intervals of 15.24 cm above the distributor plate. To prevent any solids flow from the column wire screens are provided at these ports which communicate to the pressure measuring system through a specially designed threaded connector. Similarly five ports for temperature measurement are provided at equal intervals of 30.48 cm with the first port located 22.86 cm above the distributor plates. The air-bubbles through the column and escapes into the atmosphere in a disengagement section at the top end of the column. The test section here expands into a 30.48 cm diameter tank which minimizes the liquid entrainment and instead it flows down the sloping walls of the top end of the test section into the bottom of the disengagement section, where a drain is provided for the Slurry out flow. An automatic tank drain is provided at the bottom end of the calming section to flush out any liquid which may have drained into it.

The Slurry Loop

The slurry circulation loop as shown in Figure 1 comprises of a slurry tank fitted with a stirrer to keep the slurry well mixed, a variable-speed slurry pump and a venturimeter. The slurry pump is a Moyno-SP progressing cavity pump model 331 with a delivery capacity of 2GPM at 303kPa. The flow rate is controlled by a Reliance Electric DC-1 speed controller. A bypass line across the pump is provided with a control gate valve to enable a greater flexibility in controlling the slurry flow rate to the column. A shut-off ball valve is provided near the bottom end of the column to operate the system in batch mode with no slurry circulation.

Gas-Holdup Measurement System

To determine the gas holdup in the column the pressure profile in the slurry column must be established. To obtain this a complicated measurement and control system has been devised as shown in Figures 4 and 1. The system consists of a battery of ten air purgemeters with built-in needle valves for flow control, ten pressure regulators, thirty ball valves, nine manometers, ten bottle traps connected in appropriate fashion through three-way connectors and finally communicating to the pressure ports on column wall through additional ten ball valves. The flow resistance of each line is maintained at the same level and manometers record the pressure difference between consecutive pressure ports on the column wall. The Fisher-Porter low flow rate purgemeters have a maximum capacity of 2.5 SCFH while the Matheson 3741 pressure regulators have a delivery pressure range of 12-69kPa. The air back-pressure is adjusted with the help of the regulator and purgemeter so that only a very small air flow into the column actually takes place and no liquid flows out of the column. If

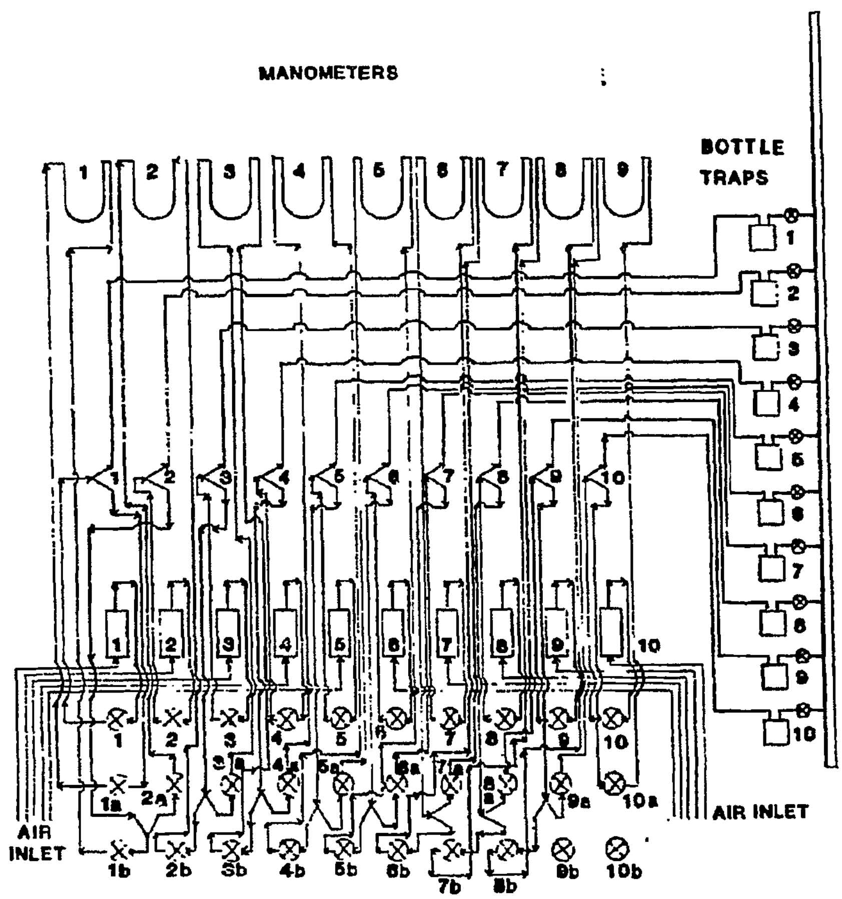


Figure 4. Schmatic of the Pressure Measurement and Control Systems.

desired the column can be isolated from this pressure measuring system by closing the valves provided at the ports of the column. Trap bottles are for the safety of the manometers in case liquid gushes out of the pressure ports.

Heat Transfer Probes

The heat transfer probe bundle assembly installation in the slurry bubble column is schematically shown in Figure 5. A typical heat transfer probe design may be detailed as currently fabricated for use in our initial phase of experimental measurements. It is 1.9 cm in outer diameter and 188 cm long. The probe has a 30.48 cm long brass section inside which a calrod heater is housed. The details of this design are shown in Figure 6A. The brass heater section at either end is provided with Teflon sleeves to minimize end heat losses. A bundle of five such probes in a typical configuration is shown in Figure 6B in which a heat transfer probe is placed along the column axis while the remaining four probes are arranged in a square arrangement. For temperature measurement iron-constantan thermocouples are bonded to the brass surface in milled grooves with technical quality copper cement. Three thermocouples are provided on the outer probes each separated by a 120^0 interval and positioned at 5.08, 15.24 and 25.4 cm from the end of the brass section. The central probe has five thermocouples and these are placed 72^0 apart at 5.08, 10.16, 15.24, 20.32 and 25.4 cm from the end of the brass section. To prevent vibration and movement of this probe bundle inside the column four spacer rods have been provided, each passing through three tubes and providing a snug-fit in the column. The probe bundle is suspended in the column by a support plate sitting on three support rods. Each probe is attached to the support plate through a support ring. The calrod heaters are energized by a HP 6274 DC power supply providing 0-60V and 0-15A with a power regulation of 0.01 percent.

The initial design of the 30.54 cm diameter Pyrex glass slurry bubble column for work at high temperatures is completed and order has been placed.

The literature search and assessment of the work done on two-and three-phase bubble columns is initiated and some progress towards the final review is accomplished.

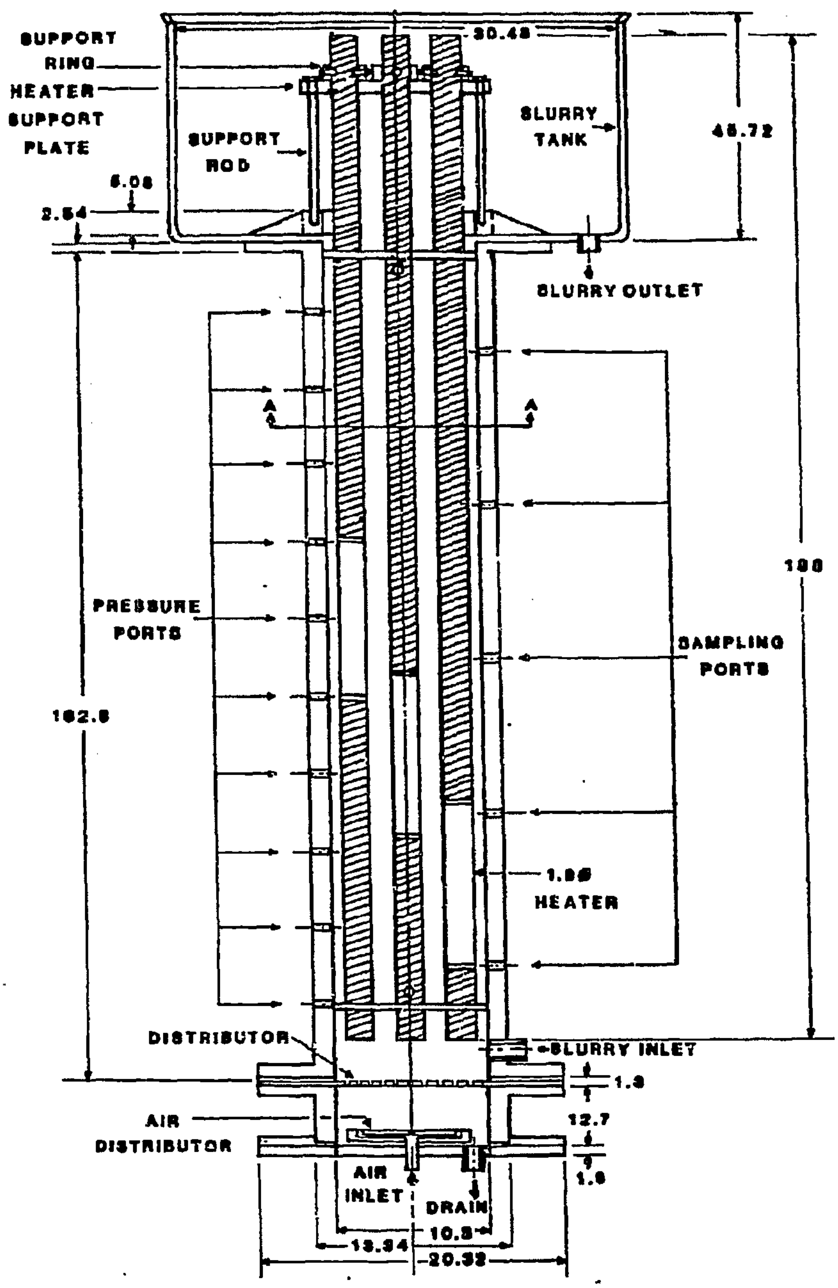


Figure 5. Schematic of the Slurry bubble Column and The Heat Transfer Probe Bundle Drawn not to Scale. All Dimensions are in cm.

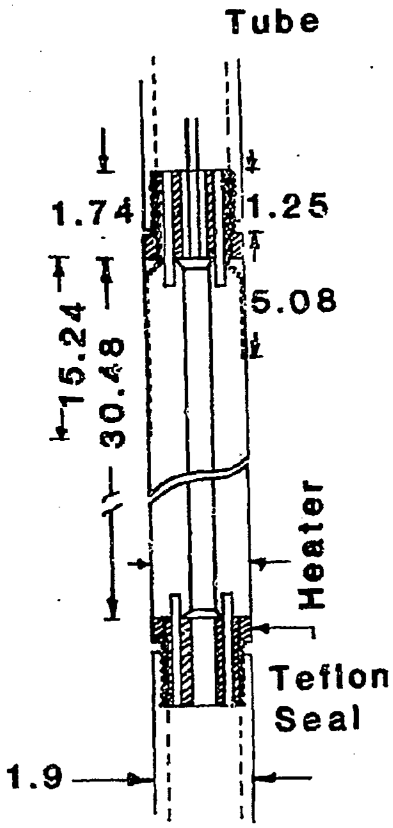


Figure 6A. Design Details of The Heat Transfer Probe. All Dimensions are in cm.

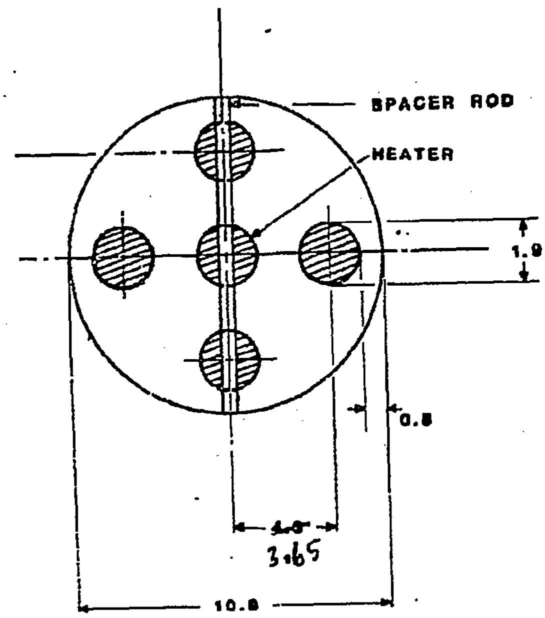


Figure 6B. Plan View of the Section A - A of the Slurry Bubble Column of Figure 5. All Dimensions are in cm.

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