IV. TASK 2 - BUBBLE COLUMN REACTOR DESIGN/CONSTRUCTION

A. DESIGN AND SELECTION OF GAS DISTRIBUTOR

In the present study, both single hole orifice plate distributors and a sintered metal plate distributor were selected for use in the 0.051 m ID columns. The 1 mm, 1.85 mm and 4 mm orifice plate distributors, and a 40 μm sintered metal plate distributor, were selected for our studies. These four distributors are similar to the ones used in previous hydrodynamic studies (see Table III-1) and/or in slurry bubble column reactors for F-T synthesis. The 1 mm and 1.85 mm orifice plate distributors satisfied the criterion presented by Mersmann (1978) for stable flow through an orifice as well as the criterion to prevent "weeping" at all superficial gas velocities investigated. The 4.0 mm orifice plate satisfied the criteria for stable flow at velocities greater than 0.024 m/s and the criterion to prevent "weeping" at velocities greater than 0.055 m/s (see Table IV-1).

For experimental studies in the 0.229 m ID and 0.241 m ID columns, perforated plate distributors (5 X 1 mm, 19 X 1 mm, and 19 X 1.85 mm) and a perforated pipe distributor (30 X 1.5 mm) were selected. The criteria presented by Mersmann were satisfied for all four distributors for all gas velocities investigated (see Table IV-1). The 5 X 1 mm perforated plate distributor was chosen because it gave jet velocities that were comparable with those in the Quicker and Deckwer (1981) study with a 0.9 mm nozzle in a 0.095 m ID column. The 19 X 1.85 mm perforated plate was chosen because it gives approximately the same orifice Weber number and the jet velocity as the 1.85 mm single hole orifice plate distributor used in the 0.051 m ID columns. Also, in the Rheinpreussen-Koppers demonstration plant gas

Table IV-1. Criteria for distributor design (evaluated at u_g=0.01 m/s).

Criterion 1:

$$\frac{u_j^2 d_o \rho_g}{\sigma} > 2$$

Criterion 2:

$$\frac{u_j^2}{g d_o}\left(\frac{\rho_g}{\rho_l - \rho_g}\right)^{5/4} \geq 0.37$$

Distributor	Criterion 1	Criterion 2
0.051 m ID column:		
1 mm	22.4	12.29
1.85 mm	3.5	0.58
4 mm	0.4[a]	0.01[b]
0.229 m ID column:		
5 X 1 mm P.Plate	326.3	203.6
19 X 1 mm P.Plate	22.6	14.1
19 X 1.85 mm P.Plate	3.9	0.65
30 X 1.5 mm P.Pipe	3.0	0.75

[a] Criterion 1 satisfied at u_g=0.024 m/s
[b] Criterion 2 satisfied at u_g=0.055 m/s

distributors with holes about 2 to 3 mm in diameter were employed (Kolbel and Ralek, 1980). We chose the 19 X 1.0 mm perforated plate distributor to study the effect of an increase in the orifice Weber number and the jet velocity (i.e. the gas velocity through the orifice) on the hydrodynamic properties. Also, this distributor is dynamically similar to the 1.0 mm single orifice plate in the 0.051 m column. The 30 X 1.5 mm perforated pipe was selected to study the effect of the distributor type and orifice diameter on the hydrodynamic properties keeping the orifice Weber number approximately the same as that for the 19 X 1.85 mm perforated plate distributor.

Mersmann (1978) presented a general criterion for stable flow through multiple orifice plates or immersion tubes with holes. For distributors with holes (d_o) smaller than the critical orifice diameter ($d_{o_{cr}}$), i.e. stable flow through the

$$d_o < d_{o_{cr}} = 2.32 \left(\frac{\sigma}{\rho_g g} \right)^{1/2} \left(\frac{\rho_g}{\rho_\ell - \rho_g} \right)^{5/8} \qquad \text{(IV-1)}$$

stable flow through the distributor is obtained when the orifice Weber number (ratio of the gas kinetic energy to the surface energy) is greater than two.

$$We_o = \frac{u_j^2 d_o \rho_g}{\sigma} \geq 2 \qquad \text{(IV-2)}$$

where the jet velocity is defined as

$$u_j = \frac{u_g d_c^2}{n d_o^2} \qquad \text{(IV-3)}$$

For perforated plates or nozzles with orifice diameters greater than

the critical orifice diameter (i.e. $d_o \geq d_{o_{cr}}$). "weeping" through the distributor can be prevented if the following criterion is satisfied:

$$Fr_o^2 \left(\frac{\rho_g}{\rho_\ell - \rho_g} \right)^{5/4} \geq 0.37 \qquad \text{(IV-4)}$$

where Fr_o is the orifice Froude number (ratio of the gas kinetic energy to the potential energy), and is defined as

$$Fr_o = \frac{u_j}{\sqrt{gd_o}} \qquad \text{(IV-5)}$$

The critical orifice diameter for FT-300 wax at 265°C is 1.73 mm (using physical properties presented in Table VI-1). The orifice Weber numbers and the orifice Froude numbers were calculated for the various distributors used in our studies for a superficial gas velocity of 0.01 m/s and are listed in Table IV-1.

For the perforated plates and perforated pipe distributors, the individual orifices were positioned so that the area about each opening was the same. This type of design is recommended for an even distribution of bubbles at the distributor (Richardson, 1961). The 19 holes composing the perforated plates were equally spaced in a triangular pitch, and the perforated pipe was a star shaped arrangement with six segments having five holes each (see Figures IV-1 and IV-2).

B. DESCRIPTION OF EXPERIMENTAL APPARATUS

Two bubble columns (0.051 m ID and 0.229 m ID, 3 m tall) made of borosilicate glass were assembled for measuring the average gas hold-up and bubble size distributions. Both columns were constructed in essentially the same manner, therefore, a detailed description of only the 0.051 m ID column is presented here.

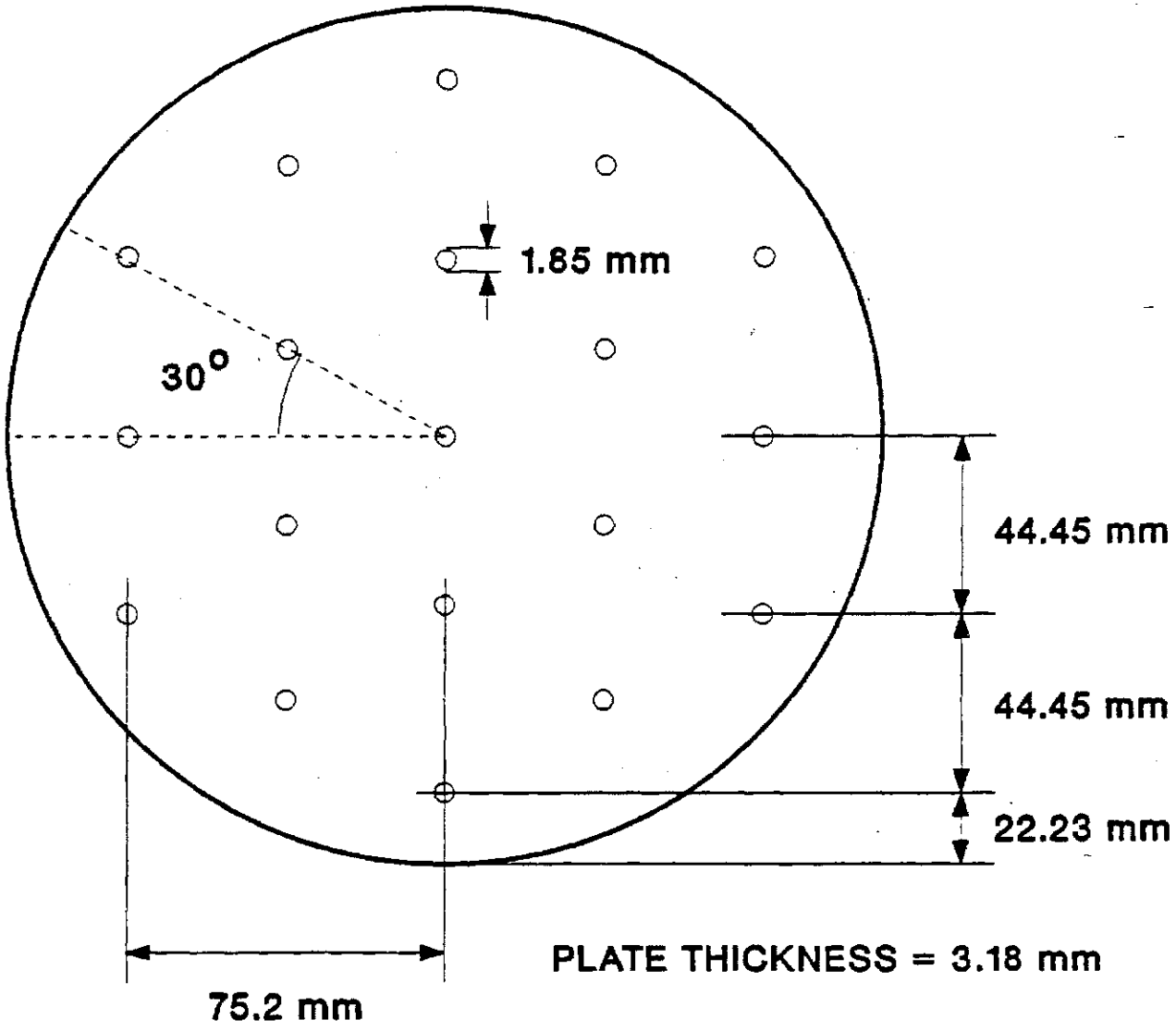


Figure IV-1. 19 X 1.85 mm perforated plate distributor

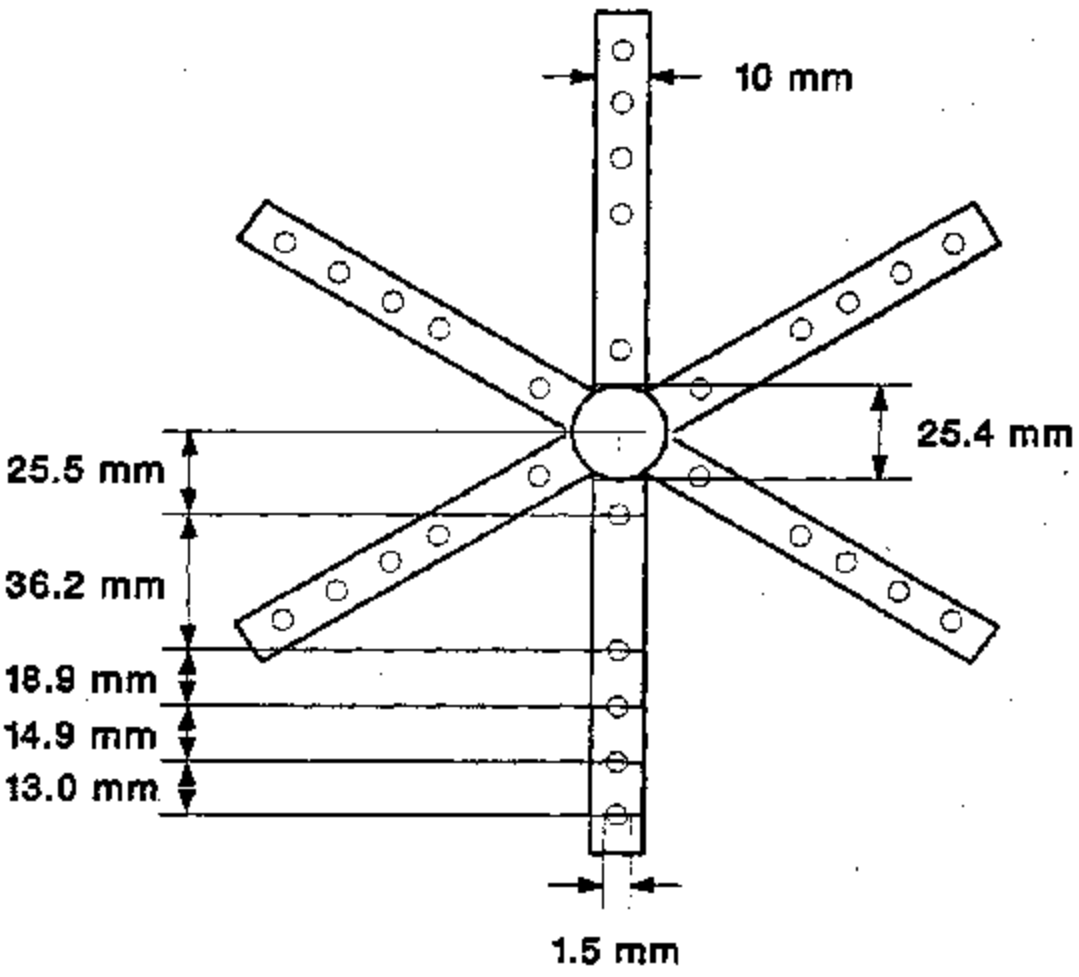


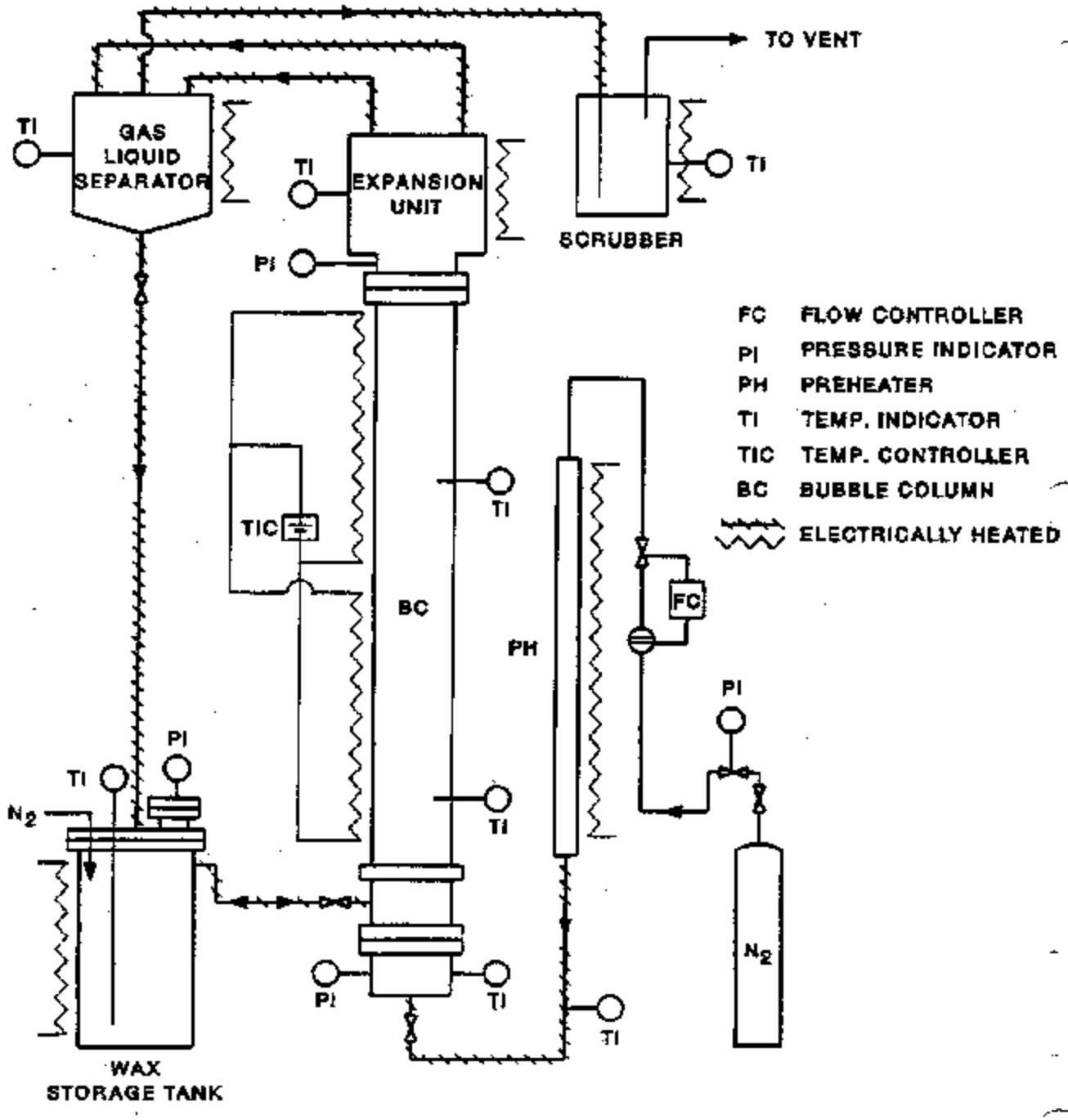
Figure IV-2. 30 X 1.5 mm perforated pipe distributor

A schematic representation of the experimental apparatus is shown in Figure IV-3. The flow rate of nitrogen from gas cylinders was measured and controlled by a mass flow meter (FC; Brooks Model 5816). For the 0.229 m ID column, a Sierra (Series 840) mass flow meter was used to measure the gas flow rate. For this column, the flow rate was controlled manually. The mass flow calibration was checked before every run using a wet test meter. The metered gas passes through a preheater (PH; electrically heated U-tube), and its temperature is monitored by two thermocouples (one located after the preheater and one just below the distributor). The thermocouples are connected to an Omega (Model 199) ten channel temperature indicator. The inlet temperature of nitrogen is manually controlled using a variable transformer. The preheated gas enters the glass bubble column (BC) through a sparger which is placed between two flanges at the bottom of the column. The column is preheated to a temperature between 150°C to 200°C using heating tapes that are wound around the column. Two Omega (Model 52) temperature controllers allow independent control of the temperature in the top and bottom halves of the bubble column. The wax in the storage tank is heated to a temperature of 150°C to 200°C before it is transported to the preheated column through a 0.013 m ID (1/2 inch) tube using a slight nitrogen overpressure. The large storage tank (0.085 m^3 capacity) was used originally for experiments in the small and large columns, however, from Run 4-1 onwards a smaller storage tank (0.009 m^3 capacity) was used for experiments in the 0.051 m ID column, while the large storage tank was used only for runs in the 0.229 m ID column.

The bubble column has four thermocouples attached to it in order to monitor its temperature. Two of these are attached to the wall of the

FIGURE IV-3

FLOW DIAGRAM OF EXPERIMENTAL APPARATUS



column (upper and lower halves of the column), while the other two are placed in thermowells located along the column axis (at approximately 0.33 and 2.00 m above the distributor). During the preheating period the thermocouples on the wall are used to control the column temperature. Once the wax is transported to the column, the column is brought to within 10 to 20°C of the desired operating temperature by gradually increasing the set point on the temperature controllers. At this point control of the column is switched to the inside thermocouples. During the entire preheating period (i.e. while wax in the column is being brought to the operating temperature) the gas flow rate is maintained at the desired start-up velocity. The disengagement unit at the top of the column, the carry-over lines from this unit to the separator, and the separator itself are maintained at temperatures above the melting point of wax (i.e > 110°C) to prevent the solidification of any entrained liquid. The hot gases leave the separator through a 0.025 m ID (1 inch) pipe and pass through the scrubber, which is filled with a mineral spirit (varsol), before it is vented to the atmosphere. The scrubber is used to recover components of the wax that evaporate from the column, and is maintained at approximately 75°C.

In addition to the two glass columns, two stainless steel columns (0.051 m ID and 0.241 m ID, 3 m tall) were also constructed for measuring axial hold-up. A complete description of these columns is given in Section V-C.