CHAPTER III
EXPERIMENTAL

3.1 Material Preparation

- Transparent Acrylic Glass Pipes
- Liquid Rotameter (Cole-Parmer, U.S.A, A-32461-42).
- Air Rotameters ((1) Cole-Parmer, A-32466-66, U.S.A., (2) Cole-Parmer, A-32466-68, U.S.A., (3) Cole-Parmer, A-32466-70, U.S.A.).
- Air Compressor (Taiwan, Fu Sheng HTA-100H).
- Static Pressure Tubes
- Manometer

3.2 Experimental Apparatus

3.2.1 Design and Experimental Setup of Two-phase Flow

Air, water, octylbenzyldimethylammonium chloride solution; (LEVENOL DM-08A, 46.6 wt.%, Kao) at 1, 2 and 3 CMC, and hexadecylbenzyldimethylammonium chloride (LEVENOL RC, 49.6 wt.%, Kao) at 1 CMC were used as the working fluids.

The main components of the system consist of the vertical test section, an air supply, liquid supply and instrumentation. Three pipes with three different inside diameters (10.75, 19, 53.15 mm) and each having a length of 3 m were used. The pipes were made from transparent acrylic glass to permit visual observation of the flow patterns. The scheme of the experimental set up is shown in Figure 3.1. At the bottom of the test column there is an inlet for the compressed air from a compressor (Taiwan, Fu Sheng HTA-100H) and flow rates were measured by a calibrated air-rotameter ((1) Cole-Parmer, A-32466-66, U.S.A., (2) Cole-Parmer, A-32466-68, U.S.A., (3) Cole-Parmer, A-32466-70, U.S.A.). Each specific liquid was pumped from the storage tank through a rotameter and mixed with air at the bottom of the test column. The flow rates of the liquids were measured by a calibrated liquid-rotameter (Cole-Parmer, U.S.A, A-32461-42). Liquid flowed upward through the main column together with air and then flowed back to the storage tank. Two static pressure tabs were installed at two axial locations with spacing of 0.4 m and were connected with a manometer which was used to measure the pressure drops along the test section. The physical properties of the liquids used in the experiment are listed in Table 3.1.

Experiments were conducted by varying air and liquid flow rates. The air flow rate was increased by small increments while the liquid (pure water or benzalkonium chloride solutions) flow rate was kept constant. The experimental conditions were as follows: air Reynolds number Re_{air}: 1.22-25480, water Reynolds number Re_{water}: 0-2740, and benzalkonium chloride Reynolds number $Re_{solution}$: 0-2740, respectively. Air and liquid temperatures were between ~31-32°C. The system was allowed to approach the steady condition before any data were taken. The pressure drops across the test section were measured at different flow rates of air and liquid. The flow regimes were observed and identified by visual observation: a video camera (Panasonic, NV-M3000) and software program (Snagit 8.0). Bubble size, slug size and void fraction of the Taylor bubble were identified and measured by a software program (Scion Image). Bubble velocity was measured by timing bubbles traveling past known distances.

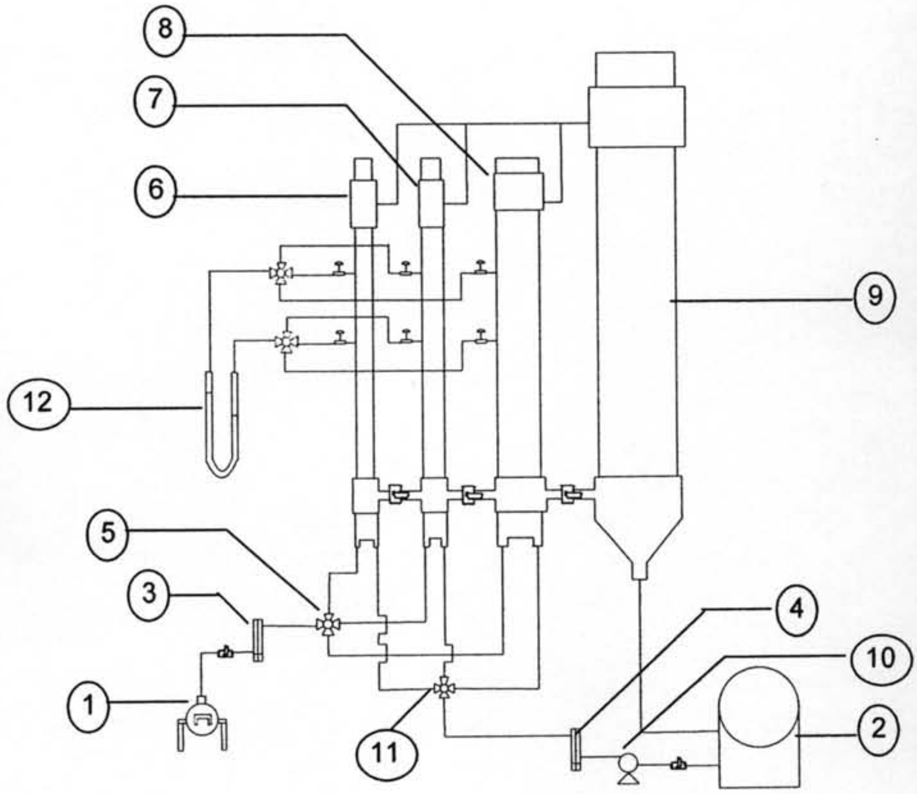

Figure 3.1 Schematic diagram of the experimental setup: 1) air compressor; 2) liquid reservoir tank; 3) air rotameter; 4) liquid rotameter; 5) air injection valve; 6) vertical tube with a diameter of 0.011 m and a length of 3 m; 7) vertical tube with a diameter of 0.019 m and a length of 3 m; 8) vertical tube with a diameter of 0.053 m and a length of 3 m; 9) overflow tube with a diameter of 0.054 m and a length of 3 m; 10) liquid pump; 11) liquid injection valve; and, 12) manometer.

Table 3.1 Physical properties of the gas and the liquids used in the experiment

Gas / Liquid	C (g/L)	μ (Pa.s)	ν (m^2/s)	ρ (kg/m^3)	σ (μS/cm)	γ (mN/m)
Air	-	1.85×10^{-5}	1.57×10^{-5}	1.18	-	-
Water	-	8.48×10^{-4}	8.52×10^{-7}	995	1.3	71.27
(C_8H_{17}-$C_9H_{13}NCl$) (1CMC)	61.5	9.73×10^{-4}	9.75×10^{-7}	998	7240	30.66
(C_8H_{17}-$C_9H_{13}NCl$) (2CMC)	123	1.189×10^{-3}	1.191×10^{-6}	998.3	12606	33.85
(C_8H_{17}-$C_9H_{13}NCl$) (3CMC)	184.5	1.317×10^{-3}	1.319×10^{-6}	998.3	17781	35.85
($C_{16}H_{33}$-$C_9H_{13}NCl$) (1CMC)	0.36	1.103×10^{-3}	1.106×10^{-6}	997.3	45.7	31.31

(C_8H_{17}-$C_9H_{13}NCl$) : Octylbenzyldimethylammonium chloride solution
($C_{16}H_{33}$-$C_9H_{13}NCl$): Hexadecylbenzyldimethylammonium chloride solution
C: concentration, μ: viscosity, ν: kinematic viscosity, ρ: density, σ: electrical conductivity, and γ: surface tension
System temperature, T = 31°C (± 1°C)

3.3 Methodology

3.3.1 Parameters

3.3.1.1 Controlled Parameters of Two-Phase Flow.

- Temperature of working fluids was controlled at 31°C by putting ice around the reservoir fluid tank.
- Outlet pressure of air compressor by using air pressure regulator. The air pressure regulator was connected with air compressor's outlet to control the system pressure. The inside pressure of air compressor is 10 bars.

3.3.1.2 Variable Parameters of Two-phase Flow

- Inside diameters (10.75, 19, 53.15 mm)

- Reynolds number of air in three columns (1.22-25480).
- Reynolds number of solution in three columns (0-2740).
- Carbon tail length of benzalkonium chloride (octylbenzyldimethylammonium chloride, hexadecylbenzyldimethylammonium chloride)

3.3.1.3 Measured Parameters of Two-phase Flow

- Boundaries of flow regimes by video camera or still photographs.
- Critical Reynolds numbers of air at each flow regime.
- Liquid levels difference in manometer for pressure gradient.
- Bubble size.
- Bubble velocity.
- Slug size
- Void fraction.

3.3.2 Experimental Procedures

3.3.2.1 Determination the Density of solution by using Syringe (SGE, Australia).

1. Weigh the empty dry beaker and record the mass.

2. Fill the beaker with solution by using syringe (100 μl) and take the mass of the filled beaker.

3. The difference between the mass of the empty beaker and the beaker when it is filled with the mass of the solution.

4. Knowing the mass of the solution and the volume of the solution (100μl), the density of the solution can be calculated using the equation:

$$\rho = \frac{M}{V} \tag{3.1}$$

3.3.2.2 Determination the Viscosity of solution by Cannon-Ubbelohe Viscometer.

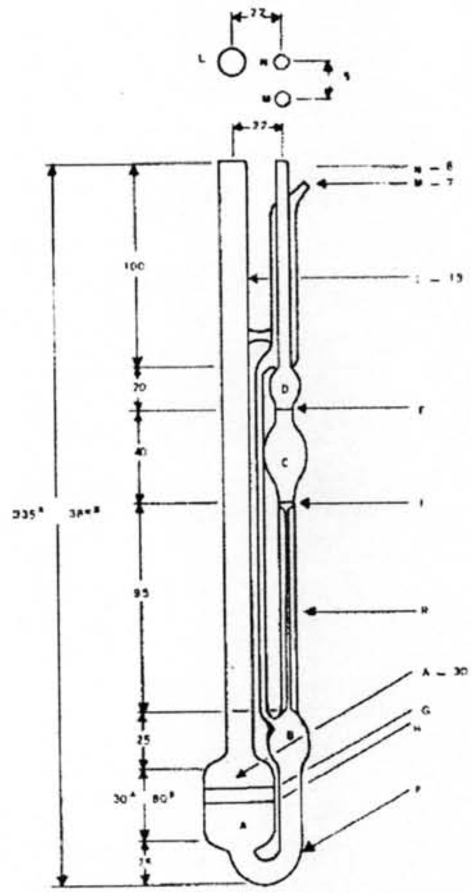

Figure 3.2 Cannon-Ubbelohde (ASTM D 446-04).

1. Use the Cannon-Ubbelohde viscometer size no. 50 which has the approximate constant equal to 0.004 (Figure 3.2).

2. Fill the solution into Cannon-Ubbelohde viscometer.

3. Mount the Cannon-Ubbelohde viscometer in the constant-temperature (31±0.3 °C) bath and keeping the tube vertical.

4. Apply vacuum to tube N and closing tube M by a finger or rubber stopper to make the solution filling upper bulb D.

5. Let the solution flow by gravitation and timing the level of solution from mark E to mark F. Use the time average value for calculating the kinematic viscosity.

6. Calculate the kinematic viscosity (v) by using equation:

Kinematic viscosity (v), mm^2/s = Time(s) × approximate constant ((mm^2/s)/s)

7. Calculate the viscosity (μ) by using equation:

$$\mu = \upsilon\rho \tag{3.2}$$

3.3.2.3 Determination of Pressure Drops in The Main Column

Two static pressure tabs are installed at two axially locations with the spacing of 0.4 m at the main column and connected with a manometer are used to measure the pressure drops along the test section. The system is allowed to approach the steady condition before any data is recorded. The manometer is filled with solution. We measured the solution levels difference in the manometer and calculated the pressure gradients for each flow regimes by following equation:

$$\left(-\frac{dp}{dz}\right) = \frac{\rho_L g h}{dz} \tag{3.3}$$

where ρ_L = liquid density (kg/m^3), g = gravitational acceleration (m/s^2), h = solution levels difference in the manometer (m), and dz = pressure taps difference (m).

The pressure drops across the test section are recorded and calculated by this method. And the values of pressure drops from the experiments are compared with the theory.

3.3.2.4 Determination of Bubble and Slug Size in The Column

Make a movie of bubble and slug flow regime by a video camera (Panasonic, NV-M3000) then convert it to DVD file. Use the software program (Snagit 8.0) to capture the bubble and slug picture from the movie. Bubble size, slug size and void fraction of Taylor bubble are identified by software program (Scion Image).

3.3.2.5 Determination of Bubble and Slug Velocity in The Column

Bubble and slug velocity was measured by timing bubbles or slugs traveling past known distances.