Chapter III

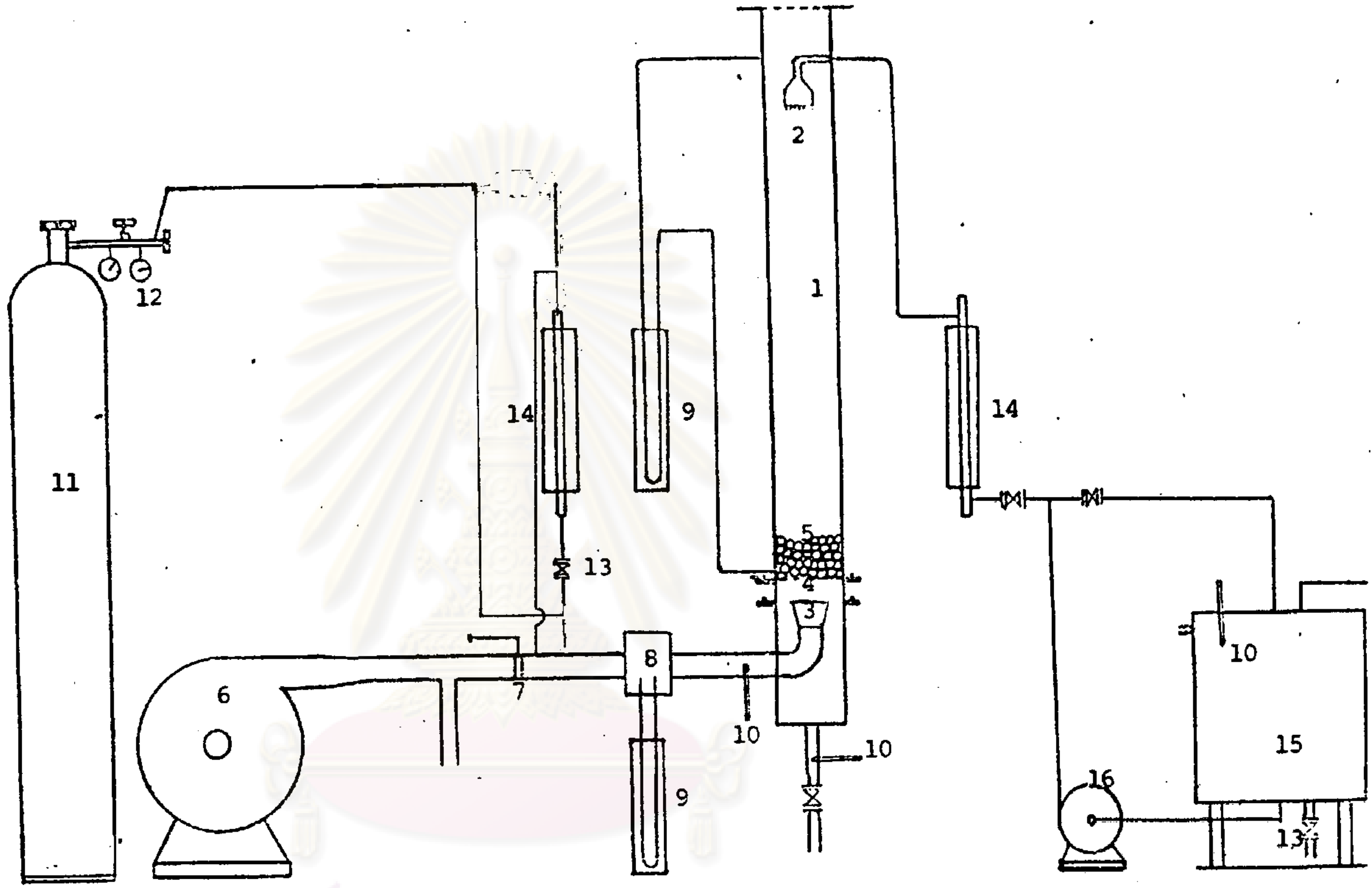
APPARATUS AND EXPERIMENTAL METHODS

3.1 The Design and Operation of a Fluidized-bed Contactor

A fluidized-bed contactor was designed and constructed. The simplified flow diagram of the fluidized-bed contactor is shown in Figure 3.1. Its main part consists of a fluidized-bed column (1), hollow polyethylene low density spheres bed (5), a high pressure blower (6), and ammonia cylinder (11), a water storage tank (15) and feed water pump (16). The assembly is shown in Figure 3.2. The assembly are to be described follows:

The main body of the fluidized-bed contactor was a 15 cm. diameter cylinder made of transparent acrylic resin. The column had wall thickness of 0.3 cm and 150 cm high. As shown in Figure 3.3, the column was divided into three parts for easily discharging packing from the column. The bed was supported by a grid at the bottom of the column (4). A conical shape gas distributor (3) as shown in Figure 3.4 was equiped under the supporting grid in order to give uniform gas distribution.

A water distributor (2) was designed and constructed specially for spreading water over the bed uniformly under high or low liquid flow rate. It was made from a bundle of copper tubes with inside diameter 0.1 cm. The diagram is shown in



1 Fluidized-bed column	5 Hollow polyethylene spheres	9 Manometer	13 Gate valve
2 Water distributor	6 High pressure blower	10 Thermometer	14 Rotameter
3 Gas distributor	7 Butterfly-valve	11 Ammonia cylinder	15 Water storage tank
4 Supporting grid	8 Orifice meter	12 Pressure gauge	16 Water pump

Fig.3.1 Schematic diagram of experimental system

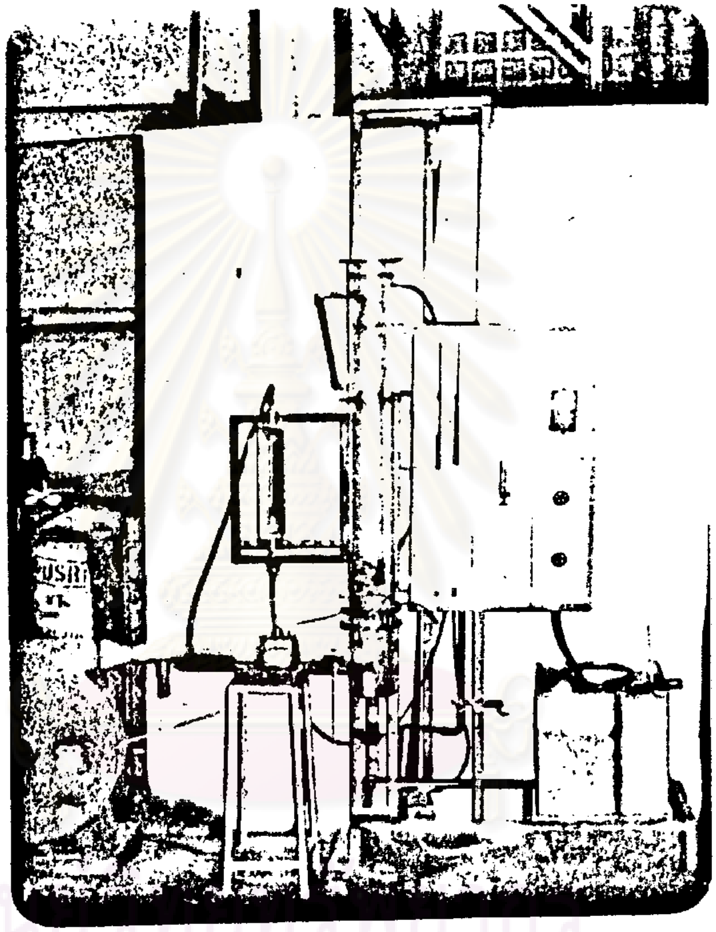


Fig3.2 Fluidized-bed contactor

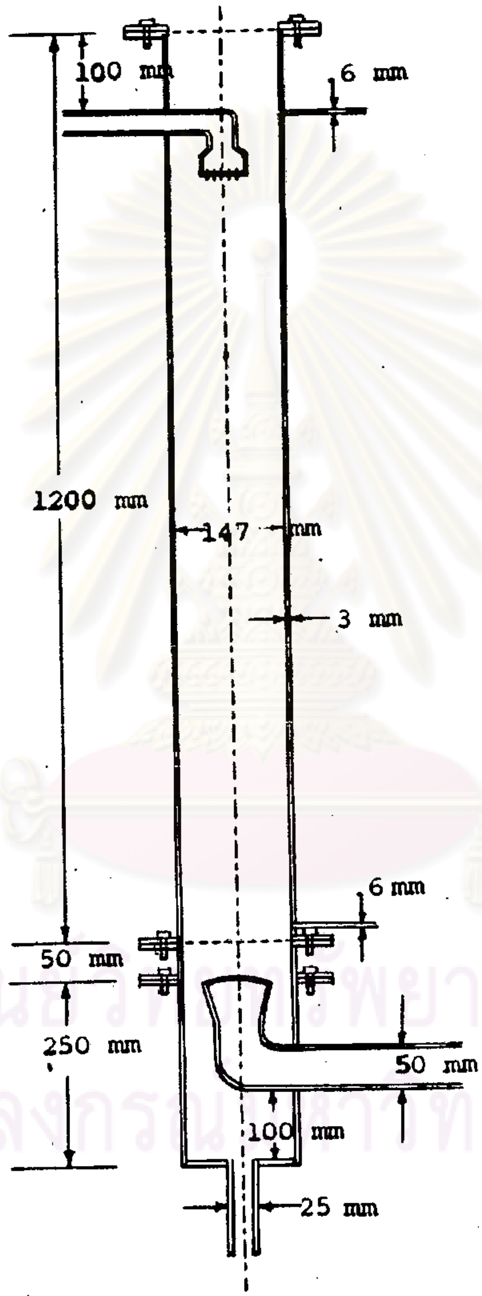


Fig.3.3 Fluidized-bed column

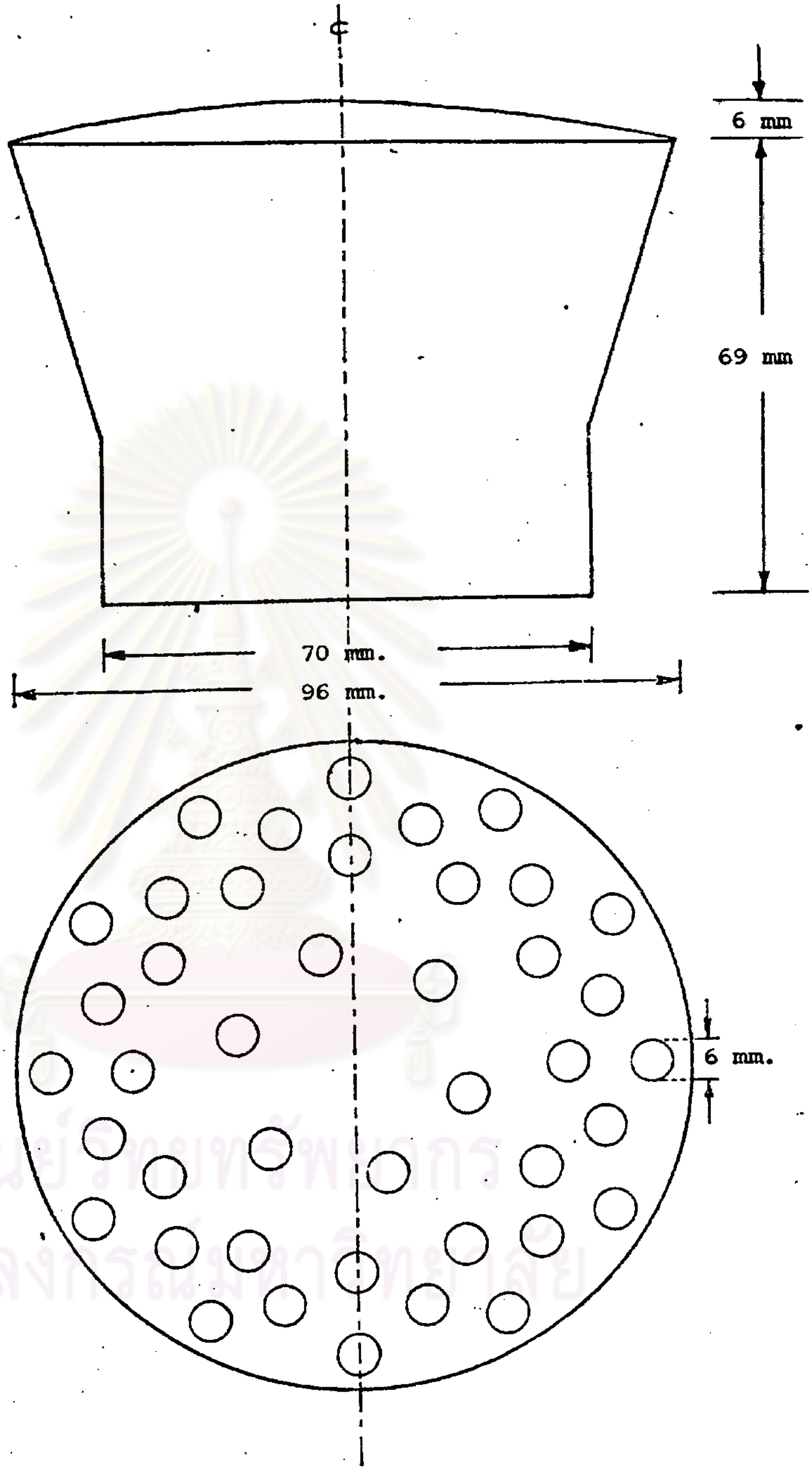


Fig. 3.4 Gas distributor

Figure 3.5. The fluidized bed was prevented to migrate from the top of the column by a grid at the top of the column. The pressure drop of the bed was measured by manometer (9) that connected between the bed.

A high pressure blower (6), fan diameter 60 cm., power by 3 H.P., 2890 rpm., flow rate of 28.8 cubic meter per min, at developed pressure 25.4 cm. of water was connected to the column by a 5 cm. inside diameter P.V.C. tube. Between the tube had a butterfly value (7) and by pass line in order to control the flow rate of air in the column. The velocity of air was measured by an orifice meter (8) and the temperature of the mixed gas was measured by a thermometer (10) before air entering the column.

Ammonia gas was supplied from the ammonia tank (11). The ammonia gas flow through gas regulator (12) in order to adjust pressure of the ammonia from the tank. The flowrate of the ammonia was measured by rotameter of Brook No.7 (14). Ammonia from the rotameter was controlled by a gate valve (13) and connected to the air supplied line between the butterfly valve and orifice meter that far enough from the column in order to have a homogeneous mixture before entering the column. The concentration of gas ammonia was reported in mole fraction.

The circulation system of water consisted of a storage tank (15), a centrifugal pump (16), and a water distributor. The storage tank was a square 45x45 cm and 45 cm high. It was constructed from a stainless steel of 0.15 cm thick. The tank had water inlet

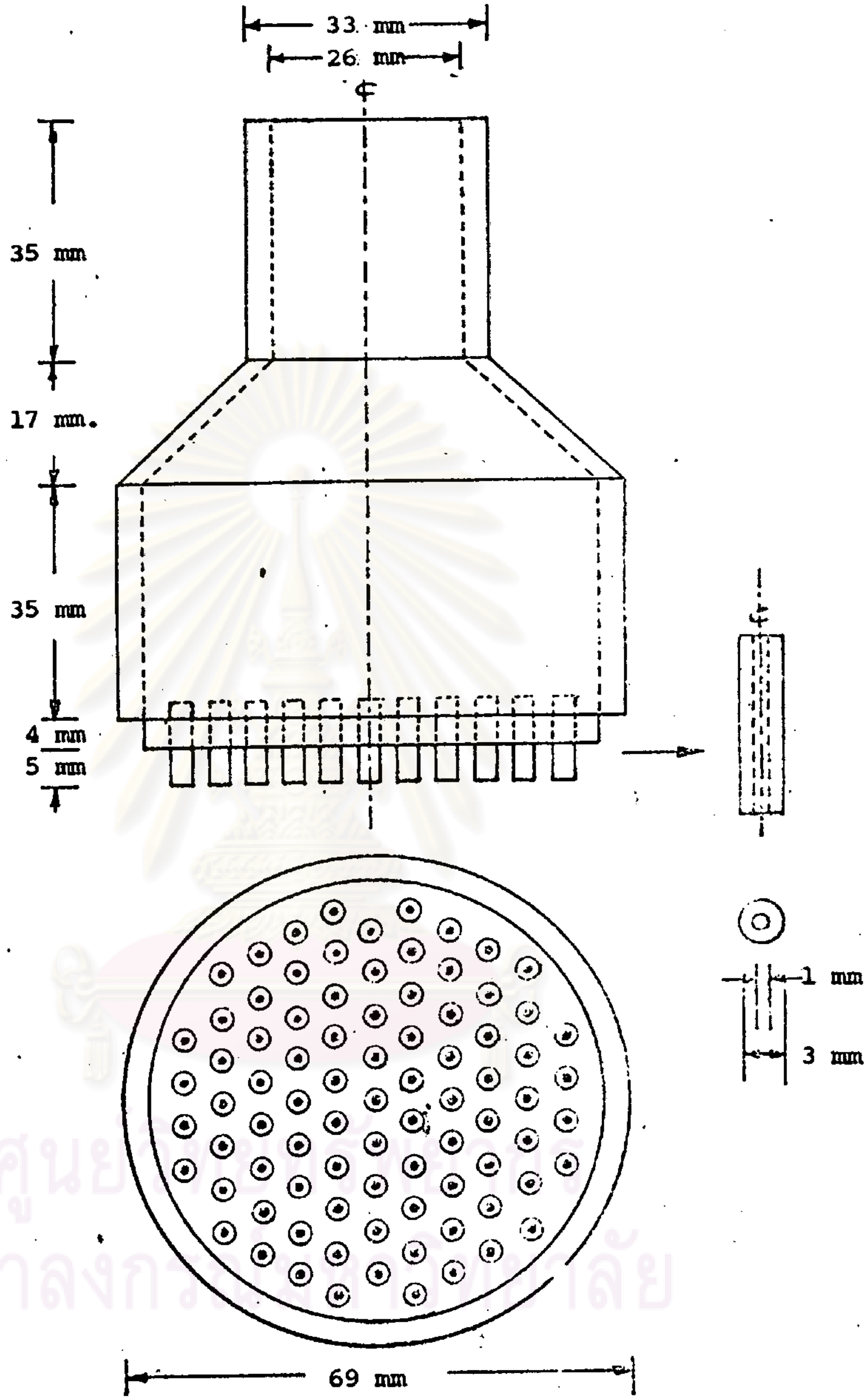


Fig. 3.5 Water distributor

at the top and had a drain line and water outlet line at the bottom. A centrifugal pump, power by 3/4 H.P., 2850 rpm., had suction line connected to the water outlet line from the tank. The flow rate of water was controlled by two valves the water by pass valve and the rotameter valve. Some of the water was by passed from the pump outlet to the top of the storage tank. The water in the storage tank was feed from tap water line and the level in the tank was controlled by the over flow line.

The fluidized bed was consisted of hollow polyethylene sphere of outside diameter 1.75 cm, 0.1 cm thickness and density of 0.2382 gm/cm^3, as shown in Figure 3.6. The spheres had three colour, red, blue and yellow for easily study the motion of the bed.

Three mercury thermometers were used for the measurement of inlet temperatures of inlet water, mixed air and the solution from the column. The measuring range of the thermometers were 0-100°C.

3.2 Preparation of Standard HCl

Standard HCl 0.1 normal was used to titrate with ammonia solution in order to determine the amount of ammonia absorbed by water in the fluidized-bed column. Standard HCl 0.1 normal was prepared by Uogel (22) method and was kept in a 20 litre tank.

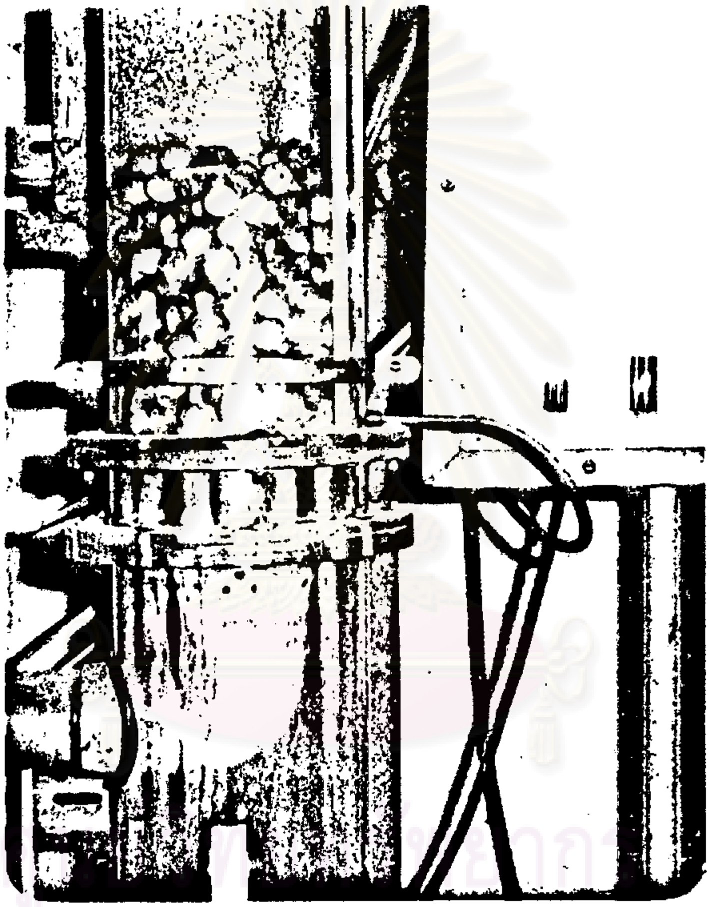


Fig.3.6 Column filled with spherical bed

3.3 Preparation of Calibration Curves and Charts

3.3.1 Calibration of Rotameter for Ammonia

A rotameter of "Brooks" No.7 was used to indicate the ammonia flow rate that entering the air stream. The meter has an attached scale of 10 divisions; each divided into 5 subdivision.

The rotameter was calibrated by varying the rate of air flowing through the meter. The air was supplied from the air-compressor. The air outlet from the meter was attached to the wet-test meter. The flow rates were calculated by recording the quantity of air flow through wet test meter in two minutes. The corresponding meter reading from the attached scale for each flow rate was read and recorded. The flow rate of ammonia were calculated from the flow rate of air by using "Brooks formular".

Coefficient for conversion × gas flow rate measured = flow rate of air

$$\text{Coefficient for conversion} = \sqrt{\frac{\rho_g}{\rho_i} \times \frac{P_i}{P_g} \times \frac{T_g}{T_i}}$$

Where subscripts i and g represent air and ammonia respectively.

The calibration data were shown in Table A.1 and plotted in Figure A.1.

3.3.2 Calibration of Rotameter for Water

A rotameter of "Brooks" Full View 8 M/2 was used to indicate the flow rate entering the fluidized-bed column. The meter has an attached scale of 10 divisions; each divided into 5 subdivisions.

The rotameter was calibrated by varying the rate of water flowing through the meter. The flow rate were calculated by recording the quantity of water collected in one minute. The corresponding meter reading from the attached scale for each flow rate was also read and recorded. The calibration data were shown and plotted in Figure A.2.

3.3.3 Calibration of Orifice Meter

Orifice meter was calibrated by varying the rate air flowing through the orifice meter. The anaemometer was attached at outlet to measure the velocity of the air and manometer reading were recorded. The calibration data were shown in Table A.3.

3.4 Experimental Variables

The process variables under studied of hydrodynamic properties are.

1. Velocity of mixed air; sixteen values of superficial air velocity between 50 to 420 cm/sec were used.

2. Bed height; four bed heights were used, i.e. 5, 10, 15 and 20 cm of bed.

3. Velocity of water; four liquid velocities were used, i.e. 0.0906, 0.1820, 0.2807 and 0.3723 cm/sec

The process variables under studied of gas film mass transfer coefficient are:

1. Mixed gas velocity; Five values of superficial gas velocities were used, i.e. 160, 232, 283, 322 and 360 cm/sec

2. Bed height; Three bed heights were used, i.e. 8.9, 15 and 20 cm of bed.

3. Liquid velocity; Five values of superficial liquid velocities were used, i.e. 0.1820, 0.2322, 0.2807, 0.3196 and 0.3728 cm/sec.

4. Gas concentration; Four mole fractions of ammonia were used, i.e. 6.41×10^{-3}, 8.10×10^{-3}, 9.61×10^{-3} and 10.86×10^{-3}.

3.5 Experimental Methods

3.5.1 Determination of Some Hydrodynamic Properties of Column

3.5.1.1 Dependence of hydraulic resistance of bed on gas velocities, liquid velocities and bed height.

The effect of gas velocity was studied at bed height 5 and 20 cm and superficial liquid velocities of 0.0906, 0.1820, 0.2807 and 0.3728 cm/sec. For each of these liquid velocities, gas velocities were varied between 50 to 420 cm/sec

The effect of liquid velocity was studied at constant gas velocity 283 cm/sec and bed heights were kept constant at 10, 15 and 20 cm. For each bed height the liquid velocities were varied between 0.0906 to 0.3728 cm/sec

The effect of bed height was also studied at constant gas velocity 283 cm/sec and liquid velocity were kept constant at 0.0906, 0.2807, 0.3728 cm/sec. The bed heights were varied between 5 to 20 cm.

3.5.1.2 Determination of minimum fluidization velocity

The determination of the minimum fluidization velocity was carried out through the measurement of aerated bed height at constant liquid mass velocities 0.0906, 0.1813, 0.2795 and 0.3713 gm/sec cm^2. Static packing heights were kept constant at 5, 10, 15 and 20 cm. For each liquid velocity and bed height, the gas mass velocities were varied from 0.1665 to 0.4573 gm/sec cm^2

3.5.1.3 Dependence of gas hold-up and liquid hold-up on liquid velocity, gas velocity and bed height.

Bed height 5, 10 and 20 cm were used, and operated at liquid velocities of 0.1820, 0.2807 and 0.3728 cm/sec. For each liquid velocity and bed height, gas velocities were varied at 157, 232, 283 and 390 cm/sec. The amount of liquid hold-up in the bed were determined by cut of method. The water inlet and outlet valves were suddenly shut and the heights of clear liquid at the bottom were measured.

3.5.2 Determinationof the Overall Gas Mass Transfer Coefficient of Ammonia

3.5.2.1 To determine the amount of ammonia in the solution

Sample 25 ml. of ammonia solution was used to titrate with standard HCl 0.1 normal and the ammonia in the solution was calculated by the equation.

$$C = \frac{N_1 V_1}{25 \times 1000}$$

3.5.2.2 Dependence of overall gas mass transfer coefficient of ammonia on process variable.

Several experiment were performed to study the effects of gas velocities, liquid velocities, bed heights and mole fraction of ammonia on overall mass transfer coefficient ($K_G a$).

The column was prepared to operate at bed height 8.9 and 15 cm. For each bed height, gas velocities were varied between 157 to 360 cm/sec. Water velocities were kept constant at 0.1820, 0.2322, 0.2807 and 0.3196 cm/sec and the mole fraction were kept constant at 6.41×10^{-3}, 8.10×10^{-3}, 9.61×10^{-3} and 10.86×10^{-3}. These set of experimental runs were designed to investigated the effect of gas velocities on $K_G a$ of ammonia.

The effects of liquid velocities were studied by using bed height at 8.9 cm. Gas velocities were kept constant at 157, 232, 283 and 322 cm/sec. Mole fraction of ammonia were 6.41×10^{-3}, 8.10×10^{-3}, 9.61×10^{-3} and 10.86×10^{-3}. For each gas velocity and mole fraction of ammonia the liquid velocities were varied from 0.1820 to 0.3728 cm/sec.

The effects of bed heights on $K_G a$ were studied by using gas velocities at 157, 232, 283, 322 and 360 cm/sec and liquid velocities at 0.2807, 0.3196 and 0.3728 cm/sec. For each constant gas velocity and liquid velocity, the height of static bed were varied from 8.9 to 20 cm. Mole fraction of ammonia were kept constant at 6.41×10^{-3}, 8.10×10^{-3}, 9.61×10^{-3} and 10.86×10^{-3}.

3.6 Experimental Procedures

Polyethylene spheres of the exact dimension were packed to a designed height. The gas velocity was supplied by the blower and was controlled by butterfly valve. The velocity could be read from the manometer that connected to the orifice meter. The water from the storage tank was pumped to the column and the flow rate was controlled. The level in the storage tank was kept constant by mean of an over flow line and the water in the tank was supplied from the tap water line. The height of fluidized bed was measured directly and the hydraulic resistance of the bed were read from the manometer that attached to the column.

To study the over all mass transfer coefficient of ammonia gas, the ammonia gas was supplied from the ammonia cylinder. Ammonia flow rate was controlled by a gate valve and a rotameter to the desired mole fraction. When steady state of absorption took place, about four or five minutes, the following data were recorded; rotameter of ammonia reading, orifice manometer reading, rotameter of water reading, temperature of inlet mixed gas, temperature of inlet water, and temperature of ammonia solution. The ammonia solution was collected as sample in a 250 ml flask and was to titrate with standard HCl 0.1 normal. The amount of HCl 0.1 normal used was recorded.