CHAPTER IV

EXPERIMENTAL

4.1 Apparatus

Standard tank configuration is used. Its diameter is 20 cm. The vessel is equipped with four symmetrically located baffles of widths T/10. The impeller used is standard six-bladed turbine positioned in the vessel axis, at the center between bottom and top of the still liquid, see Figure 4.1. To make sample spheres of different densities, the equipment for coating sample spheres is used, see Figure 4.2.

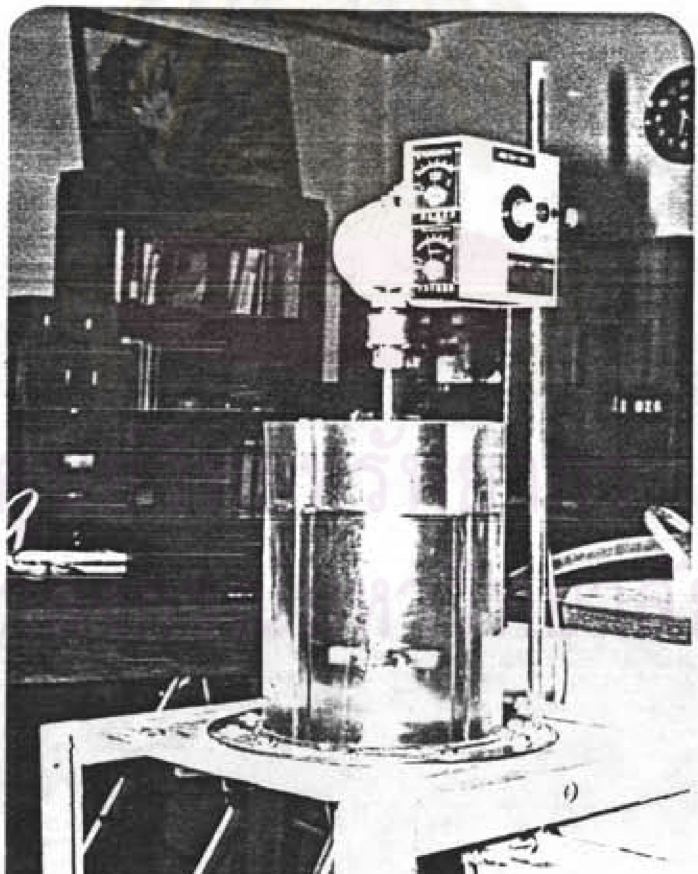

Figure 4.1 Standard six-bladed turbine and the vessel

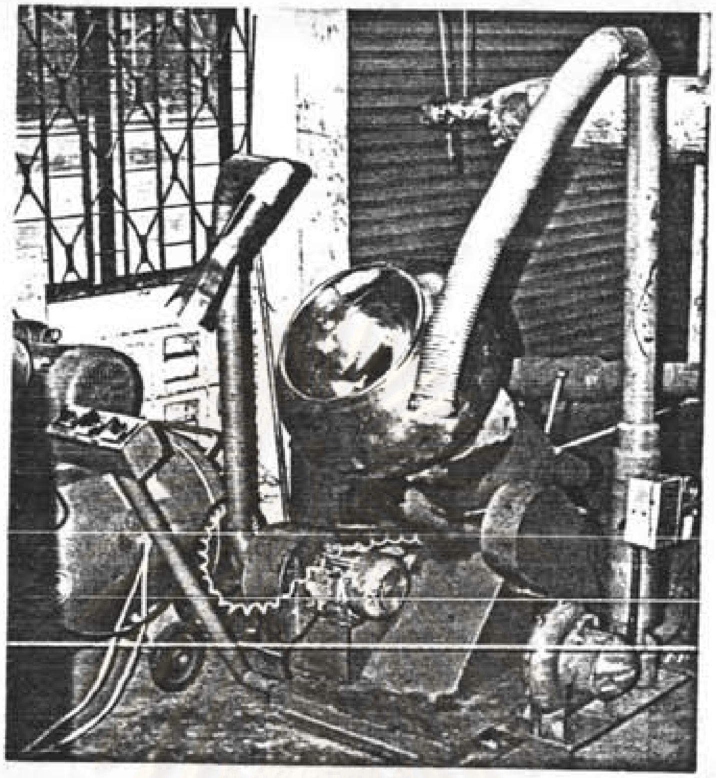

Figure 4.2 The equipment for coating sample shperes

4.2 Material

In order to have density difference between solid and liquid, tap water, 13 wt %, 20 wt % and 35.5 wt % sucrose in water are chosen as the experimental liquid. Benzoic acid is selected as the experimental sample spheres because of its low solubility, high purity and stability. In order to produce sample spheres of different densities, benzoic acid is coated on glass beads, polystyrene spheres, plastic particles type 1 and type 2, see Figure 4.3. The method of coating sample spheres is demonstrated in Appendix A.

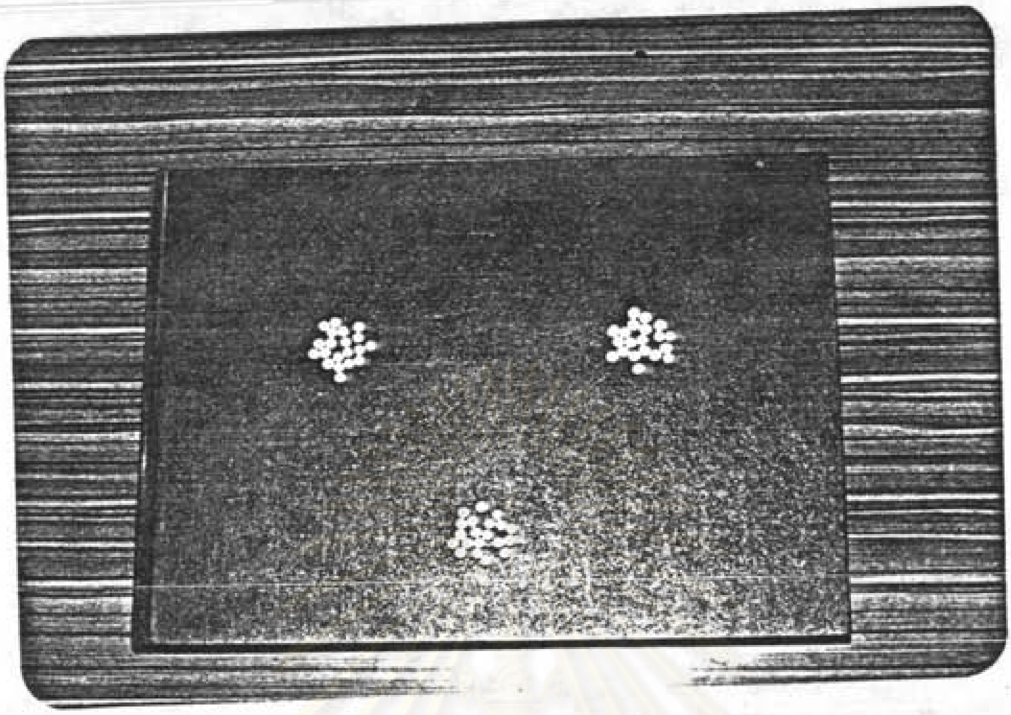

Figure 4.3 Some coated sample spheres

To make each group of solid spheres having uniform characteristic, the equipment for coating is used. A little binding agent is used in the coating operation. Coated solid spheres pass sieve number 4 to obtain particle diameter 4.76 mm.

4.3 Determination of Mass Transfer Coefficient [25]

The determination of mass transfer coefficient concerns the measuring of concentrations before and after diffusion.

The mass transfer coefficients are determined from the knowledge of material balance of the solid mass exchanged during the experiment. The transfer coefficients are calculated from the relation:

$$k \quad = \quad m/A\Delta c_{ML} \qquad \text{.......................(4.1)}$$

where

m is the difference between the initial and final weights of particles per time.

A is mean value for surface area

$$\Delta c_{ML} = c-c_o/\ln[c_S-c_o/c_S-c]$$

$$= c_f-c_o/\ln[(c_S-c_o/c_S-c_f) \quad \ldots\ldots\ldots\ldots\ldots(4.2)$$

4.4 Experimental Procedure

The general experiment is simple. The following is an outline of the procedure for each run. The vessel is filled with liquid to a level equal to its diameter. The temperature of liquid is adjusted to the value required; this temperature never varied more than 1 °C during any one of the experiments performed. Impeller drive is supplied by an adjustable speed motor. The impeller speed is adjusted to proper range and measured by hand tachometer at the top of the drive shaft, see Figure 4.4. Fluctuations are no greater than 1 to 2 rpm from any set speed ever occurred. The impeller speed range has been fixed so that the lower limit corresponded to solid particles suspension defined so that no particle remained for more than two seconds on the bottom of the tank. Before introducing the solid particles in the vessel, they are weighed. A weighed amount of solid particles are suddenly introduced, and a stop watch is started simultaneously. After a measured period, five minutes, the solid particles are quickly recovered and dried in the oven at 60 °C for one hour and a half to make sure that solid particles are absolutely dried.

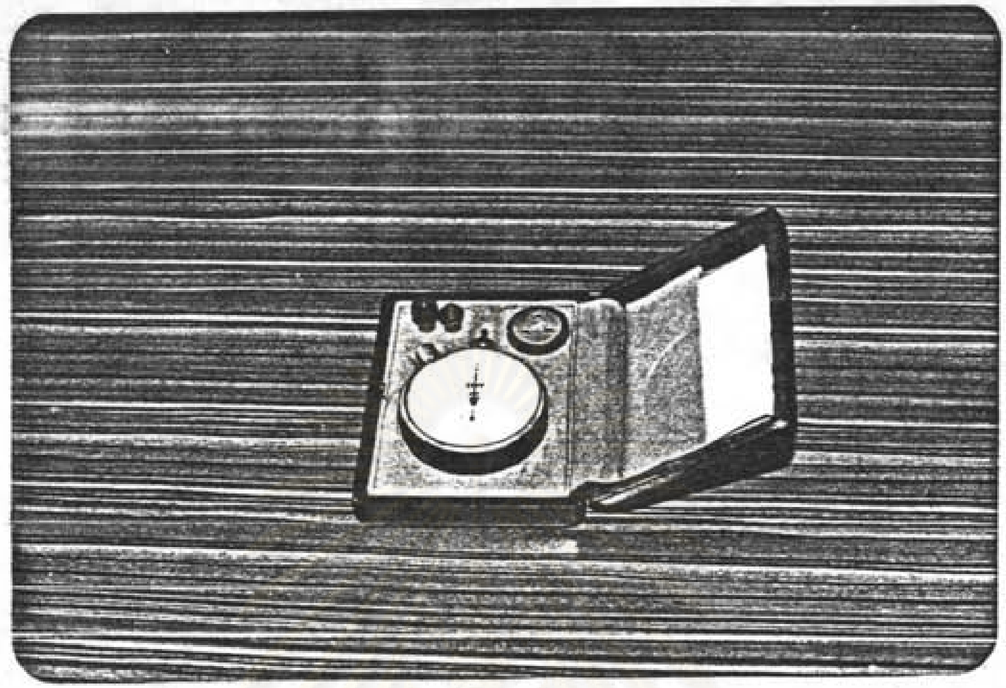

Figure 4.4 Tachometer

The dried pellets are then placed in a dessicator and left at room temperature. After one hour the solid particles are weighed. In each run ten solid particles of uniform diameter have been used. The range of rotation speeds studied are from 250 to 550 rpm and temperature are from 25 to 45 °C. At least 450 such runs were made.

The densities of solid particles are determined, see Appendix B. Solubilities of benzoic acid vs temperature obtained from [32] are shown in Appendix C. Viscosity and density of water vs temperature obtained from [33] are shown in Appendix D and E respectively. Viscosity of 13 wt %, 20 wt % and 35.5 wt % sucrose in water vs temperature obtained from [34] are shown in Appendix F.

Density of 13 wt %, 20 wt % and 35.5 wt % sucrose at various temperatures are determined by using pycnometer and the values are shown in Appendix G. The diffusion coefficient of benzoic acid in water are obtained from [35], [36].

The diffusion coefficient of benzoic acid in sucrose solution is calculated from the relation [1]:

$$D_v = D_w(\mu_w/\mu_s) \qquad \text{..................(4.3)}$$

where D_w = diffusivity of benzoic acid into water at 25 °C = 92.78×10^{-7} cm^2/s [35], [36]

μ_w = viscosity of water at 25 °C = 0.95 cp [33]

μ_s = viscosity of sucrose solution at temperature of run

Values of diffusion coefficient of benzoic acid in water and sucrose solution are shown in Appendix H.

Data of Seidell [37] indicate that the addition of sugar to water has no effect on the solubility of benzoic acid. Hence, the solubility of benzoic acid in 13 wt %, 20 wt % and 35.5 wt % sucrose solution are assumed to be the same as in pure water.

The mass transfer coefficient is determined by using Equation (4.1). For a dissolution process, the driving potential is $c = c_s - c$. The saturation concentration values c_s are only a function of temperature, see Appendix C. The concentration, c is calculated from the mass dissolved, m and the liquid volume. Diffusivity of samples vs temperature are obtained from literature, see Appendix H. To calculate the dimensionless number, Sh_p, Re_p, Sc and Mv see Appendix I. The blank test and the calculation of precision are shown in Appendix J and K respectively. Appendix M is curve fitting for the relation between Sherwood number and Reynolds number or Schmidt number or Density group. Appendix N is the determination of the constant, r in the correlations. Prediction accuracy of the present general correlations are shown in Appendix O.

Weighings are made on a Satorius automatic balance having on accuracy of $\pm$ 0.0001 g.

4.5 Dimensional Analysis of Mass Transfer Correlation

In solid liquid agitation the entire mass transfer relation can be expressed by seven independent variables as

$$k = f(d_p, T, (\rho_s - \rho_l), \rho_l, \mu, D_v, \omega)$$

In agitated solid liquid systems, the appropriate equation is

$$kd_p/D_v = f(d_p T \omega \rho_l/\mu, \mu/\rho_l D_v, \rho_s - \rho_l/\rho_l)$$

$$Sh_p = f(Re_p, Sc, Mv)$$

where

kd_p/D_v is the Sherwood number referred to solid particle, Sh_p

$d_p T w \rho_l/\mu$ is the Reynolds number referred to solid particle, Re_p

$\mu/\rho_l D_v$ is the Schmidt number, Sc

$\rho_S - \rho_l/\rho_l$ is the Density group, Mv

In this work the results will be correlated in terms of particle Sherwood number as a function of particle Reynolds number, Schmidt number and Density group. Tank particle and solid particle diameter are constant. Solid particles are interested because of different densities.

Table 4.1 Summary of Solid-Liquid System for this Present Work

Benzoic acid coated on	Density (g/cm^3)	Density difference at various temperatures for each system (g/cm^3)														
		Water					wt % sucrose in water									
							13		20				35.5			
		25	30	35	40	45	30	35	25	30	35	40	25	30	35	40
glass beads	1.4020	0.4050	0.4063	0.4079	0.4098	0.4110	0.3553	0.3573	0.3239	0.3243	0.3248	0.3264	0.2496	0.2510	0.2529	0.2536
polystyrene spheres	1.2367	0.2397	0.2410	0.2426	0.2445	0.2465	0.1900	0.1920	0.1586	0.1589	0.1595	0.1611	0.0843	0.0857	0.0876	0.0883
plastic particles I	1.1866	0.1896	0.1909	0.1925	0.1944	0.1964	0.1399	0.1419	0.1085	0.1088	0.1094	0.1110	0.0342	0.0356	0.0375	0.0382
plastic particels II	1.1239	0.1269	0.1283	0.1298	0.1317	0.1337	0.0772	0.0792	0.0452	0.0452	0.0468	0.0483	-0.0285	-0.0253	-0.0252	-0.0245

Range of speed of agitation for each system is between 250-550 rpm