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# APPENDICES

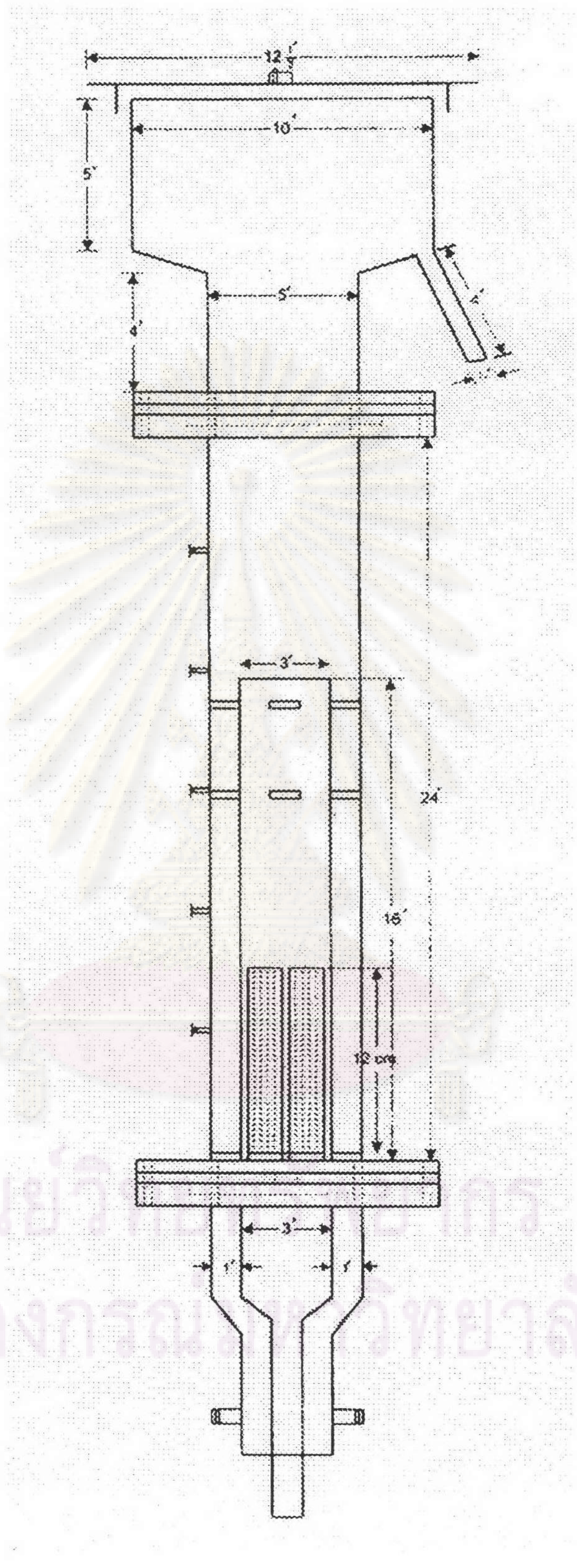


Figure 1. Schematic diagram of fluidized bed unit

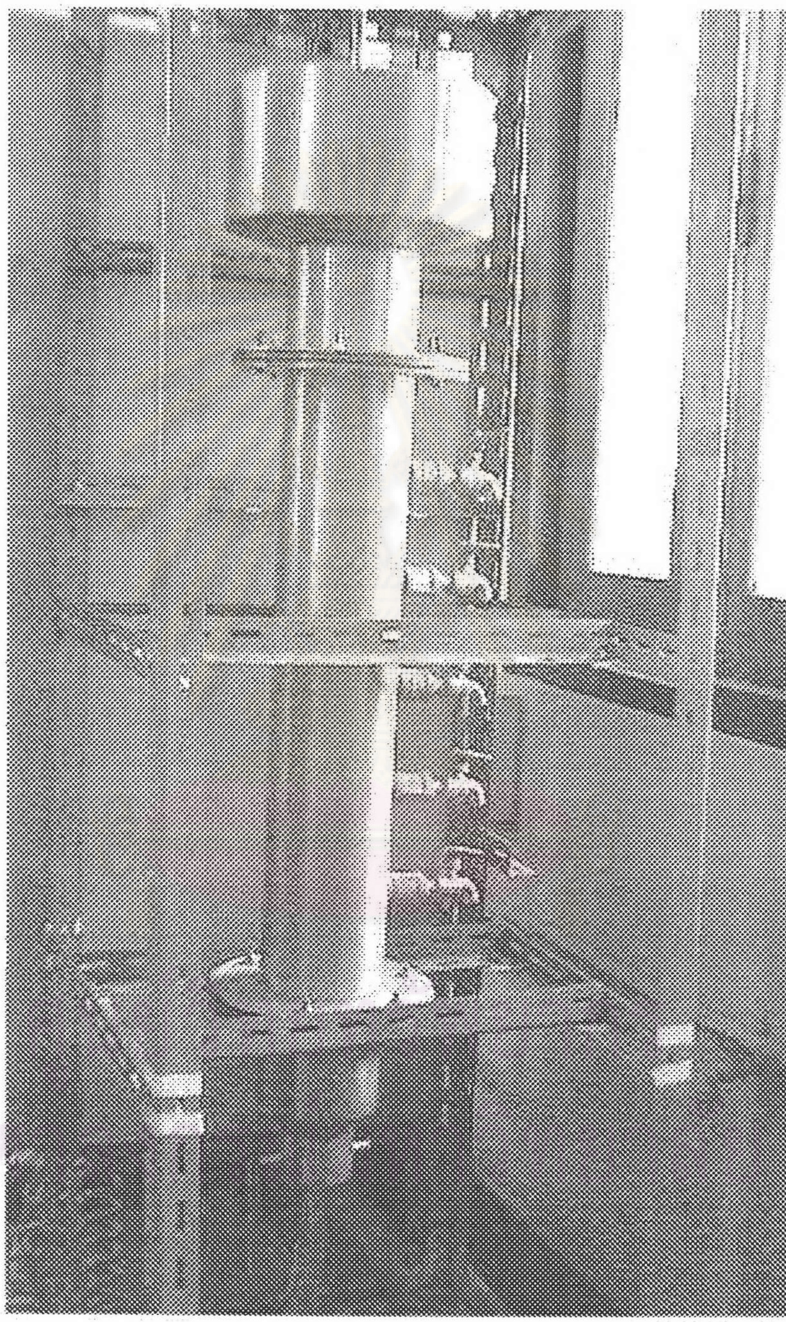

Figure 2. Photograph of fluidized bed column

Calculation of terminal velocity, $u_t$

$$U_t = (4g(\rho_s - \rho)D_p/3C_D\rho)^{1/2}$$

For sphere particle, the terminal velocity can be found by trial and error after guessing $N_{Re,p}$ to get an initial estimate of Drag coefficient, $C_D$, dimensionless (where the relationship between $C_D$ and Reynolds' number for spheres in shown in Figure 4.6 p 36)

| $D_p$(m) | $u_0$(m/s) | $\rho_s$(kg/m$^3$) | $\rho$(kg/m$^3$) | $\mu$(kg/m s) | g(m/s$^2$) | $N_{Re,p}=D_pu_0\rho/\mu$ | $C_D$ | $u_t$ |
|---|---|---|---|---|---|---|---|---|
| 0.001 | 0.0017 | 2500 | 999 | 0.001 | 9.800 | 1.99 | 24 | 0.029 |
| 0.001 | 0.029 | 2500 | 999 | 0.001 | 9.800 | 28.46 | 2.1 | 0.097 |
| 0.001 | 0.097 | 2500 | 999 | 0.001 | 9.800 | 96.22 | 1.1 | 0.134 |
| 0.001 | 0.134 | 2500 | 999 | 0.001 | 9.800 | 132.95 | 0.9 | 0.148 |
| 0.001 | 0.148 | 2500 | 999 | 0.001 | 9.800 | 146.98 | 0.85 | 0.152 |
| 0.001 | 0.152 | 2500 | 999 | 0.001 | 9.800 | 151.24 | 0.84 | 0.152 |

## Advantages and Disadvantages of Fluidized Beds for Industrial Operation

The fluidized bed has desirable and underdesirable characteristics. Its advantages are

1. The smooth, liquid-like flow of particles allows continuous automatically controlled operations with easy handling.
2. The rapid mixing of solids leads to close to isothermal conditions throughout the reactors; hence the operation can be controlled simply and reliably.
3. In addition, the whole vessel of well-mixed solids represents a large thermal flywheel the resists rapid temperature changes, responds slowly to abrupt changes in operating conditions, and gives a large margin of safely in avoiding temperature runaways for highly exothermic reactions.
4. The circulation of solids between two fluidized beds makes it possible to remove (or add) the vast quantities of heat produced (or needed) in large reactors.
5. It is suitable for large-scale operations.
6. Heat and mass transfer rates between fluid and particles are high when compared with other modes of contacting.
7. The rate of heat transfer between a fluidized bed and an immersed object is high; hence heat exchanges within fluidized beds require relatively small surface areas.



Its disadvantages are

1. For bubbling beds of fine particles, the difficult-to-describe flow of gas, with its large deviations from plug flow, represents inefficient contacting. This becomes especially serious when high conversion of gaseous reactant or high selectivity of a reaction intermediate is required.
2. The rapid mixing of solids in the bed leads to nonuniform residence times of solids in the reactor. For continuous treatment of solids, this gives a nonuniform product and poorer performance, especially at high conversion levels. For catalytic reaction, the movement of porous catalyst particles,

which continually captures and release reactant gas molecules, contributes to the backmixing of gaseous reactant, thereby reducing yield and performance.

3. Friable solids are pulverized and entrained by the fluid and must be replaced.
4. Erosion of pipes and vessels from abrasion by particles can be serious.
5. For noncatalytic operations at high temperature, the agglomeration and sintering of fine particles can require a lowering in temperature of operations, thereby reducing the reaction rate considerably.

**Microalgal cultivation**

The three tested microalgal strains, *Chlorella ellisopedia* TISTR 8260, *Chroococcus sp*. TISTR 8623 and *Chlorococcum sp.* TISTR 8509 were obtained from Microbiological Resources Centre (MIRCEN), Thailand Institute of Scientific and Technological Research (TISTR). *Chlorella ellisopedia* was cultured in modified N-8 medium. *Chroococcus sp.* and *Chlorococcum sp.* were cultured in modified BG-11 medium. However, all of supplies and medium must avoid contamination by using sterile techniques with autoclave (120°C & 15 min).

*Procedure*

1. Microalgal cells were subcultured from vial to 100 mL flasks that were filled an adequate amount of medium. After cells were brought up until they changed in green colour overall the flask. Subculturing was performed from 100 mL flask to 500 mL flask.
2. After culture had become dense for its present flask, 2 or 3 flasks were poured to carboy that was already filled 10 L of medium.
3. The cultivation of microalgae was incubated at $24 \pm 1^{\circ}C$, and continuously illuminated by cool-white fluorescent lamps at the light intensity of 100 $\mu E \cdot m^{-2} \cdot s^{-1}$ and the culture was sparged with air.
4. Before harvest, 1.5-2 month after subculturing to carboy, cells density was counted by counting chamber and microscope.

*Culture media*

BG-11

This medium is used for successfully for most cyanobacteria. Vitamin B12 may be added for those species that require it. Use f/2 vitamin solution.

Reference: Rippka, R., J. Deruelles, J. Waterbury, M. Herdman and R. Stanier. 1979. Generic assignments, strain histories and properties of pure cultures of cyanobacteria. J. Gen. Microbiol. 111: 1-61

| Stock | Stock solution | mL/Litre |
|---|---|---|
| 1. $NaNO_3$ | 150 g/L | 10 mL |
| 2. $K_2HPO_4.3H_2O$ or *$K_2HPO_4$ | 40 g/L or *30 g/L | 1 mL |
| 3. $MgSO_4.7H_2O$ | 75 g/L | 1 mL |
| 4. $CaCl_2.2H_2O$ | 36 g/L | 1 mL |
| 5. Citric Acid combined with Ferric | 6 g/L | 1 mL |
| Ammonium Citrate | 6 g/L | 1 mL |
| 6. EDTA | 1 g/L | 1 mL |
| 7. $Na_2CO_3$ | 20 g/L | 1 mL |
| 8. Trace Metal solution See below 1 mL | | |

Adjust pH to approximately 7.5. (Initial pH is approximately 8.5.) When making Trace Metal Solution: solid media, you can add agar directly to medium or make double strength medium and double strength agar solution, then after autoclaving combine the two. OPTION: 0.5 g/L of HEPES buffer can be added to the final medium as a buffer. FeCl3 and EDTA added in a 1:1 ratio may be substituted.

| Substance | g/Litre |
|---|---|
| 1. $H_3BO_3$ | 2.86 g |
| 2. $MnCl_2.4H_2O$ | 1.81 g |
| 3. $ZnSO_4.7H_2O$ | 0.222 g |
| 4. Na $MoO_4.5H_2O$ | 0.390 g |
| 5. $CuSO_4.5H_2O$ | 0.079 g |

| | |
|---|---|
| 6. $Co(NO_3)_2.6H_2O$ | 0.0494 g |

Dissolve each of the above substances separately prior to adding the next on the list.

N-8

| Stock | Stock solution | mL/Litre |
|---|---|---|
| 1. $Na_2HPO_4.2H_2O$ | 2.6 g/50 mL | 5 mL/L |
| 2. $KH_2PO_4$ | 7.4 g/50 mL | 5 mL/L |
| 3. $CaCl_2$ | 0.3 g/150 mL | 5 mL/L |
| 4. FeEDTA | 0.3 g/150 mL | 5 mL/L |
| 5. $MgSO_4.7H_2O$ | 1.5 g/150 mL | 5 mL/L |
| 6. $KNO_3$ | 10 g/50 mL | 5 mL/L |
| 7. Na2SO3 | 1.74 g/150 mL | 5 mL/L |

Trace Metal Solution:

| Substance | g/Litre |
|---|---|
| 1. $Al_2(SO_4)_3.18H_2O$ | 3.58 g |
| 2. $MnCl_2.4H_2O$ | 12.98 g |
| 3. $CuSO_4.5\ H_2O$ | 1.83 g |
| 4. $ZnSO_4.7H_2O$ | 3.2 g |

Dissolve each of the above substances separately prior to adding the next on the list.

# BIOGRAPHY

Miss Piradee Soontornsatid was born on 4th August 1979 in Bangkok, Thailand. She finished her secondary school from Satriwithaya School in 1995. After that, she studied in the major of Industrial Chemistry in Faculty of Science at Kingmongkut Institute Technology of Ladkrabang. She continued her study for Master's degree in Chemical Engineering at Chulalongkorn University. She proudly participated in the Particle Technology and Material Processing group and achieved her Master's degree in April 2004.