A STUDY OF MULTISTAGE/MULTIFUNCTION COLUMN FOR FINE PARTICLE SEPARATION

Quarterly Technical Report

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ABSTRACT/EXECUTIVE SUMMARY

Hydrodynamic tests were continued in this quarter. Liquid circulation velocities are the characteristic parameters in the multistage column. Conductivity tracer response method has been set up for liquid circulation velocities measurement. The period of dampened sinusoidal conductivity signals can be clearly identified and then converted into linear and superficial liquid velocities.

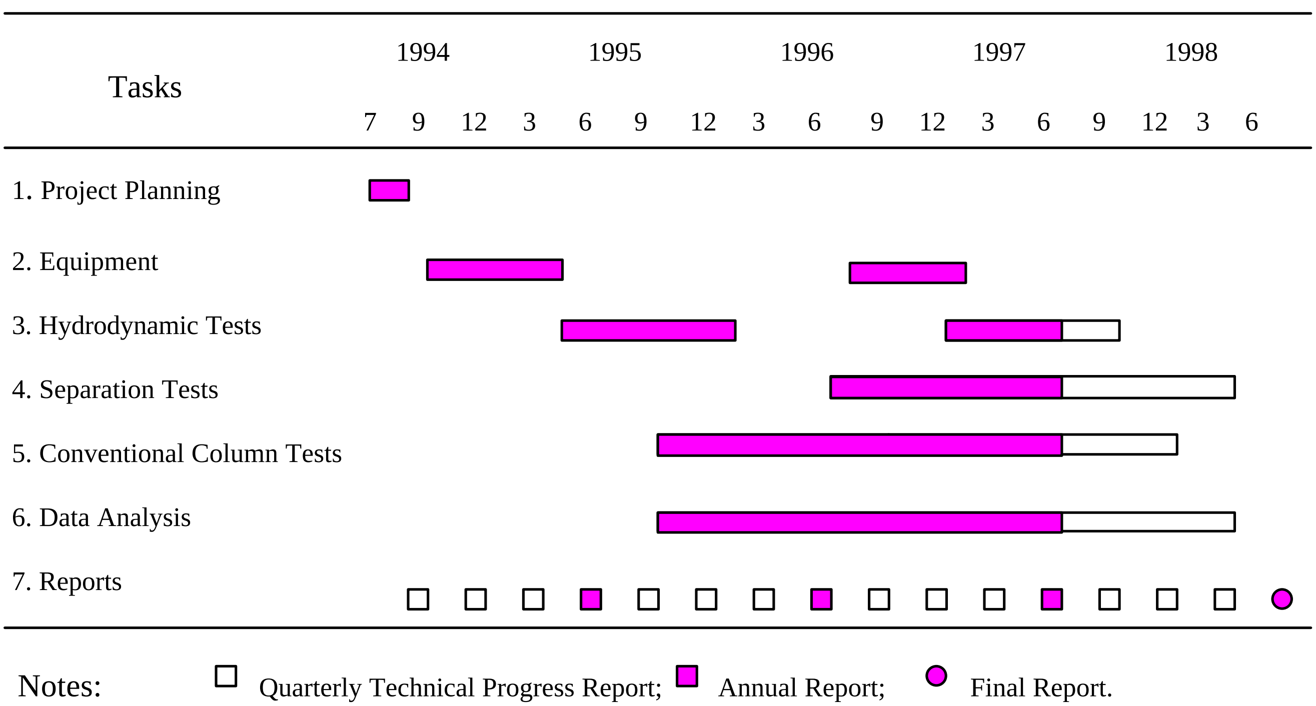
TABLE OF CONTENTS

1.0 INTRODUCTION

The overall objective of the research program is to explore the potential application of a new invention involving a multistage column equipped with concentric draft-tubes (hereafter referred to as **the multistage column**) for fine coal cleaning and other fluid/particle separation processes. The research work will identify the design parameters and their effects on the performance of the separation process. The results of this study will provide an engineering basis for further development of this technology in coal cleaning and in the general areas of fluid/particle separation.

In the last quarter, we continued to carry out the hydrodynamic experiments for establishing a process model for engineering design and scale-up. In compliance with DOE grant Amendment No. M003, the project schedule is adjusted. Table 1.1 shows work accomplished to date.

Table 1.1 Project Schedule



2.0 RESULTS AND DISCUSSION

2.1 Task 1: Project Planning

This task was completed in September 1994[1].

2.2 Task 2: Equipment Design and Construction

The equipment modification was completed in January, 1997[2].

2.3 Task 3: Hydrodynamic Tests

2.3.1 Liquid Circulation Velocity

The liquid circulation velocity is measured using tracer response technique. A dampened sinusoidal type of response as depicted in Figure 1 is detected at some location down stream the tracer injection point. The time difference t_d between adjacent peaks is taken as the mean circulation time. The mean linear liquid velocity can be calculated using the following equation(3,4):

$$u_L = \frac{d_{electrode}}{t_d} \tag{2-1}$$

The superficial liquid velocity and mean linear liquid velocity can be mutually converted using the following equation

$$u_L = \frac{U_L}{1-\varepsilon_r} \tag{2-2}$$

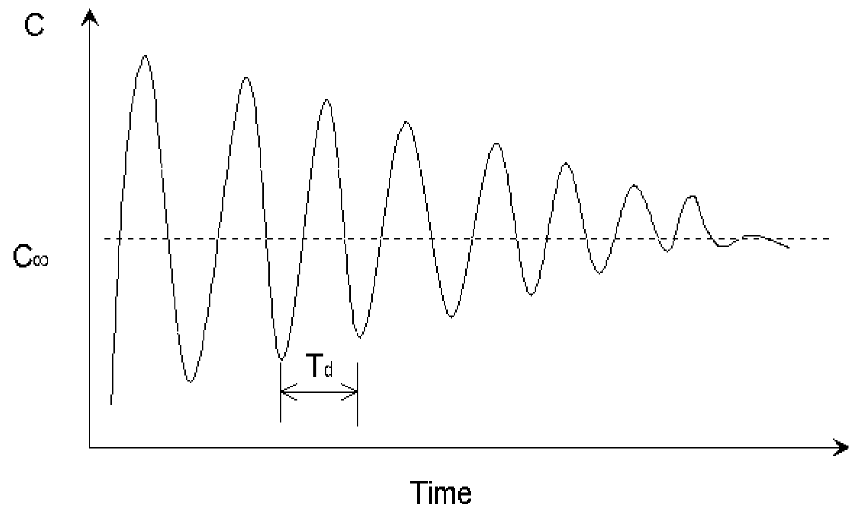


Figure 1 Typical Response to Pulse Input of Tracer in Loop Flow Reactor

In the multiple draft tube case, the distance traveled by circulating fluid in one loop path is $2(H_{dr}+H_T+0.5H_B)$. The superficial velocity in the riser and the downcomer can be calculated using the following expressions (see Appendix A for detailed derivation):

$$U_r = \frac{H_{dr} + H_T + 0.5H_B}{t_d}\left(1 - \varepsilon_r + \frac{1 - \varepsilon_d}{AR}\right) \qquad (2\text{-}3)$$

and $$U_d = U_r AR \qquad (2\text{-}4)$$

In this study, conductivity probes are used as the detecting electrodes. The measurements are performed with an analog conductivity meter (Cole-Parmer 19100) equipped with a flat-bed recorder (Linseis L-120E). The tip of the probes are covered by fine screen caps to avoid small bubbles entering the conductivity cell and causing interference. Saturated Potassium Chloride (KCl) at room temperature is used as the tracer because of its high solubility and conductivity. Two (2) conductivity probes are installed 18 inches apart in each stage.

One of the recorded the tracer responses is shown in Appendix B. Chart speed was 2 mm/s. Two Conductivity probes recorded the dampened conductivity respectively, as the KCl dispersed into the liquid.

2.4 Task 4: Separation Tests

No separation test was performed in this reporting period.

2.5 Task 5: Conventional Column Tests

No conventional column test was conducted in this quarter

2.6 Task 6: Data Analysis

Mathematical treatments will be presented upon the completion of the hydrodynamic tests.

3.0 CONCLUSION AND WORK FORECAST

In this quarter, efforts were mainly devoted to establish the measuring method of liquid velocities. Conductivity tracer and response method has been successfully set up. Data collection and analysis can be expected in the next quarter.

Research work to be continued in the next quarter will include the following:

1. Examine the liquid circulation velocities at different levels of surfactant dosages.
2. Measure the gas bubble sizes and distribution using photographic/image analysis methods.

4.0 REFERENCES

1. "***A Study of Multistage/Multifunction Column for Fine Particle Separation***", **Quarterly Technical Progress Report**, (July 8 - September 30, 1994), Chemical & Petroleum Engineering Department, University of Pittsburgh, Submitted to U.S. Department of Energy, PETC, January 20, 1995.

2. "***A Study of Multistage/Multifunction Column for Fine Particle Separation***", **Quarterly Technical Progress Report**, (October 1 - December 31, 1997), Chemical & Petroleum Engineering Department, University of Pittsburgh, Submitted to U.S. Department of Energy, FETC, December 10, 1996.

3. Chisti, M. Y., Halard, B., and Moo-Young, M., "Liquid circulation in airlift reactors," Chemical Engineering Science, Vol. 43, No. 3, (1988), pp. 451-457.

4. Lu, W. J., et al, "Liquid velocity and gas holdup in threee-phase internal loop airlift reactors with low-density particles," Chemical Engineering Science, Vol. 50, No. 8, (1995), pp. 1301-1310.

Appendix A

DERIVATION OF EQUATIONS FOR LIQUID CIRCULATION VELOCITY CALCULATION

The geometric variables are illustrated in Figure A. In a multiple draft tube case, the distance traveled by liquid is 2 (H_{dr}+H_t+0.5H_B), half in riser and half in downcomer. The total time elapsed in one complete loop is the sum of the time spent in the riser side and in the downcomer side:

$$t_d = \frac{L}{u_r} + \frac{L}{u_d} \qquad \text{(A-1)}$$

where L denotes the half distance H_{dr}+H_t+0.5H_B in either side; u_r, and u_d are linear velocities in riser and downcomer.

Applying the relationship between the linear velocities and superficial ones which is described in Equation (2-2), Equation (B-1) becomes:

$$t_d = \frac{L}{\left(\frac{U_r}{1-\varepsilon_r}\right)} + \frac{L}{\left(\frac{U_d}{1-\varepsilon_d}\right)} \qquad \text{(A-2)}$$

The superficial liquid velocities in the riser and downcomer are related based on mass continuity. Substitution of this relation into Equation (B-2) gives:

$$t_d = L\left(\frac{1-\varepsilon_r}{U_r} + \frac{1-\varepsilon_d}{AR(U_r)}\right) \qquad \text{(A-3)}$$

where AR is the area ration of the riser to the downcomer, i.e.

$$AR = \frac{A_r}{A_d} \qquad \text{(A-4)}$$

The rearrangement of Equation (B-3) yields the explicit expressions for superficial velocities:

$$U_r = \frac{L}{t_d}\left(1 - \text{e}_r + \frac{1 - \text{e}_d}{AR}\right) \tag{A-5}$$

and

$$U_d = U_r AR \tag{A-6}$$

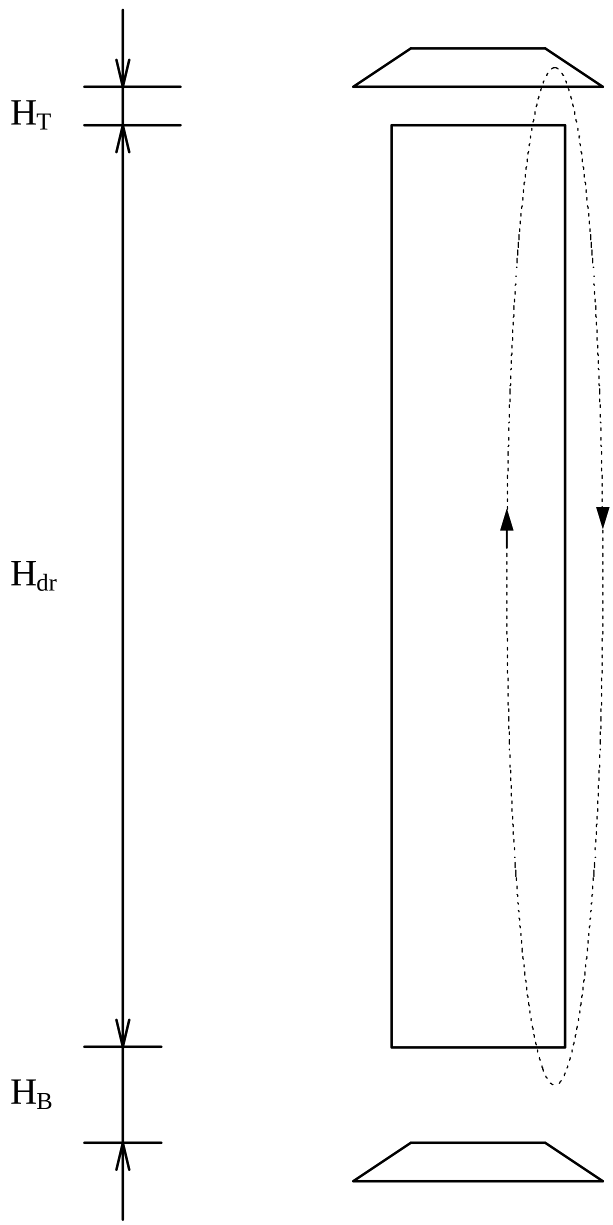


Figure A   Illustration of Flow Path for Superficial Velocity Derivation

Appendix B

CURVE SHAPE

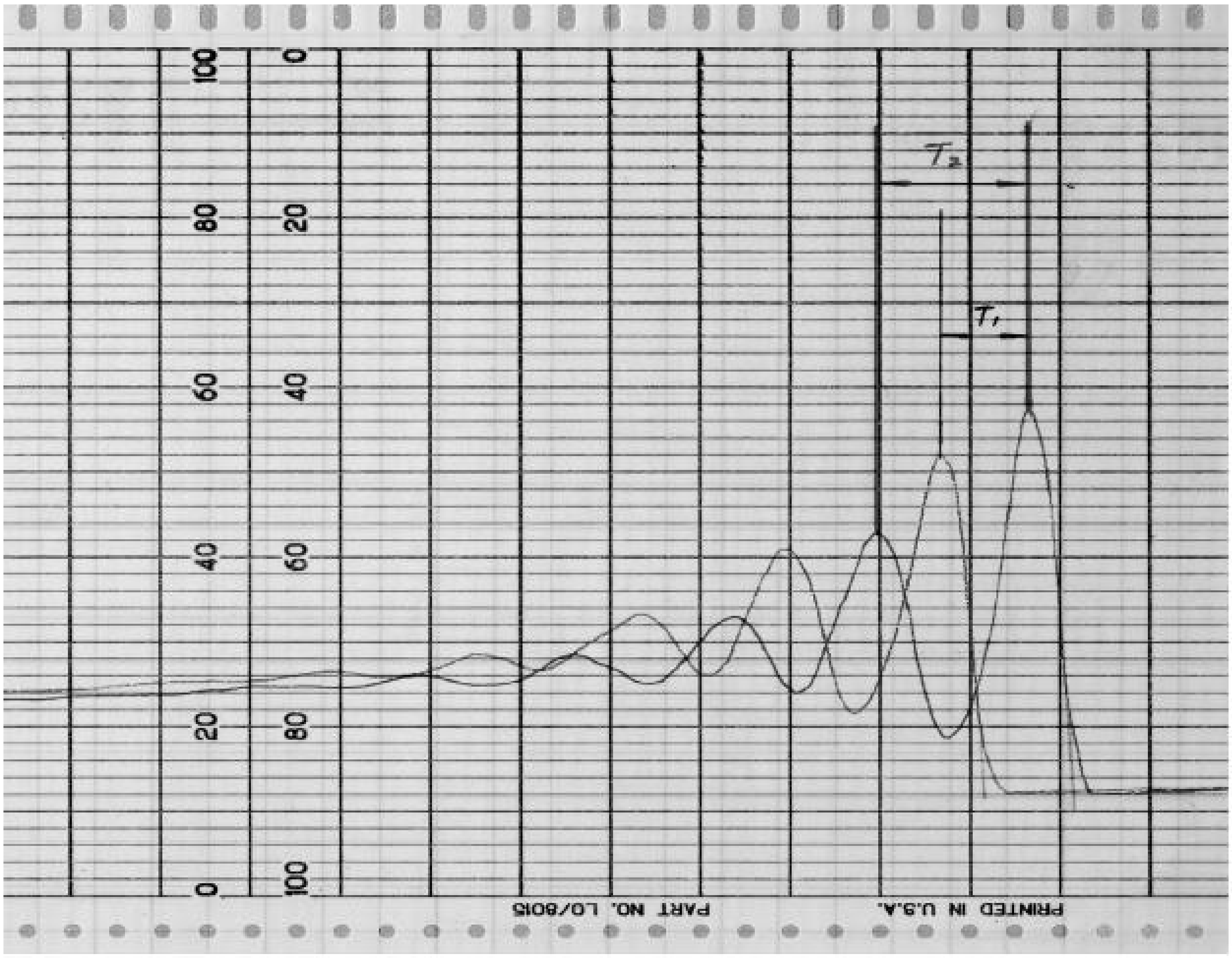


Figure B   Recorded signal curve