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Technical Progress Report No.7

Investigation of Heat Transfer and Combustion in the Advanced Fluidized Bed Combustor (FBC)

to

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SUMMARY

This technical report summarizes the research performed and progress achieved during the period of April 1, 1995 to June 30, 1995.

The particle flow measurements on mass flux of radial directional were conducted and discussed. The particle dispersion is dense near the wall and relatively dilute in the core region. It was found that the particle mass flux generally increases along the radial direction adjacent to the wall of the test chamber. An interface at a certain radius adjacent to the chamber wall is expected where interacting forces are dynamically balanced.

The dense suspension layers and the dilute suspension regions were observed in the freeboard of the exploratory cold model (6 "I.D.). Based upon observations and measurements, the general behavior of suspension layers was summarized in this report.

The bench-scale advanced FBC test chamber (10" I.D.) was designed and fabricated to better understand how gas recirculating flow, particle suspension flow, and particle elutriation rate are affected by swirling flow in the freeboard of the test chamber. The measurements of the gas and particle flows will be conducted in this bench-scale model.

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SECTION 1

Measurements of Particle Flow Field

1.1 Distribution of Particle Mass Flux in Radial Direction

Measurements of particle mass flux were conducted in the 6-inch diameter test chamber of the laboratory-scale cold model [1]. Figure 1 shows the particle mass flux distribution in the radial direction. Curve A is measured at H*=6 and curve B at H*=5. The particle dispersion is dense near the wall and relatively dilute in the core region. It was found that the particle mass flux generally increases along the radial direction adjacent to the wall of the test chamber.

It is noticed that the mass flux difference in curve B amounts to more than one order of magnitude. As shown in Figure 1, a high mass flux was detected near the wall and core region. Under the interaction of strong centrifugal force, particles in the chamber undergo a spiral trajectory and are thrown towards the chamber wall by the swirling gas flow. On the other hand, when particles bounce from the chamber wall, turbulent diffusion and inward radial fluid drag tend to push the particles back toward the chamber center.

An interface at a certain radius adjacent to the chamber wall is expected where interacting forces are dynamically balanced [2]. At this balancing interface, the particle mass flux exhibits as a peak, which indicates the plane of higher particles density.

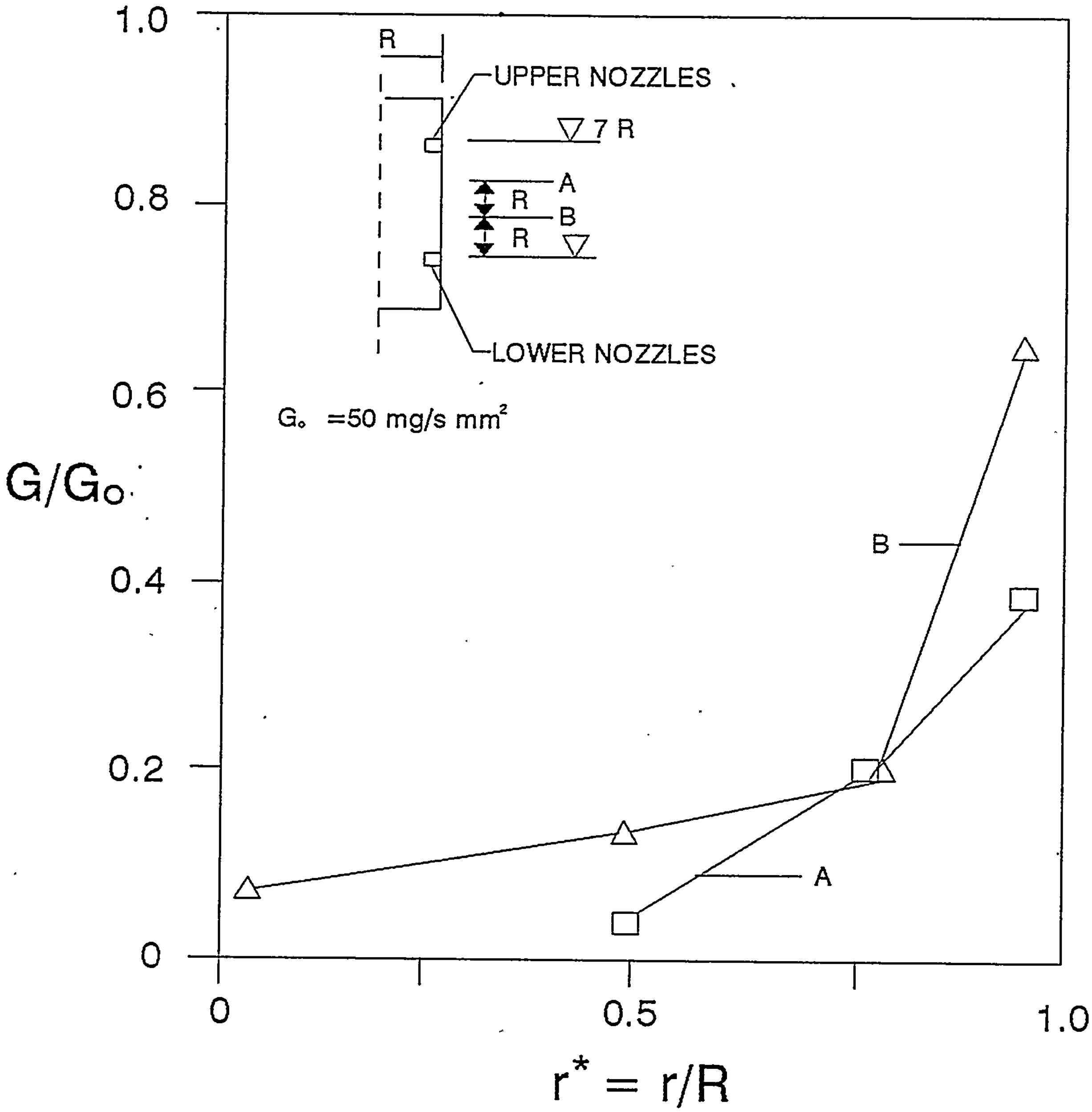

Figure 1 The Radial Distribution of Normalized Particle Mass Flux in the Exploratory Model

1.2 Particle Suspension Layer in the Freeboard

When primary and secondary air velocities are maintained in certain specific ranges, dense suspension layers and dilute suspension regions were observed in the freeboard of the exploratory cold model (6" I.D.).

The characteristics of the suspension layers are radial particle distribution, layer thickness, and location, which can be controlled by changing the primary and secondary air velocities. Based upon observations and measurements, the general behavior of suspension layers can be summarized as follows:

(1) Tangential air injection is necessary to generate the suspension layer. This layer is formed immediately above the plane of the injected air. The suspended particles are relatively dense near the freeboard wall and dilute in the core region. Radial air injection does not directly affect the formation of the suspension layers. Instead, it has a detrimental effect to the existing suspension layers.

(2) Once the suspension layers are established, their location and thicknesses are insensitive to small changes in the secondary air velocity. Excessively high secondary velocities may cause flow instability and fluctuation of the suspension layer.

(3) Particles are fluidized and entrained into the freeboard by the primary air. Primary air velocity affects the total number of particles and hence the particle density in the suspension layer. High primary air is not desirable to the formation of suspension layers because of serious particle elutriation.

1.3 Particle Residence Time

Measurement of particle residence time is generally difficult for mixed-size particles in a swirling flow field. A simplified gross measurement of particle residence time, namely the distribution function method, will be used in this study.

According to stochastic process theory, fuel particles passing through a test chamber follow a random process, but possess a deterministic residence times distribution [3]. This distribution function F(t) is defined as the accumulated number fraction of particles whose residences are less than t. The distribution density function f(t) is defined as the number percentage dN of particles whose residence times lie between t and t + dt. when N is the total number of particles. Therefore, dN/N equals to f(t)dt. With this notation, normalization condition can be shown as follows:

$$\int_{0}^{\infty} f(t)\,dt = \int_{0}^{\infty} dN/N = 1 \qquad (1)$$

and the particle residence time distribution function F(t) is

$$F(t) = \int_{0}^{t} f(t)\,dt \qquad (2)$$

Thus, the averaged particle residence is then given by

$$\bar{t} = \int_{0}^{\infty} t\, f(t)\,dt \qquad (3)$$

F(t), f(t) are generally discrete when measured experimentally. Thus, Equation (3) becomes

$$\bar{t} = \frac{\Sigma\, t_i\, f(t_i)}{\Sigma\, f(t_i)}$$

SECTION 2

Design and Fabrication of Bench-scale Cold Model

2.1 Design of the Test Chamber

As shown in Figure in Figure 2, the bench-scale advanced FBC test chamber was designed and fabricated to better understand how gas recirculating flow, particle suspension flow, and particle elutriation rate are affected by swirling flow in the freeboard of the test chamber.

This test chamber was made of a transparent acrylic tube (Plexiglas) with 10" I.D. to facilitate visual observation. The test chamber was physically divided into several parts by a Plexiglas perforated distributor plate, the wind box below the distributor and the exhaust pipe and freeboard above the distributor as show in photograph of Figure 3. The key components of the cold models, such as the secondary air nozzles were designed to be adjustable in the tests. Eight nozzles were mounted in the freeboard at different levels to provide secondary air. Each level of the secondary air injection consists of four-equally spaced nozzles along the circumferential wall of the test chamber.

Two high pressure blowers will be used to provide primary air and secondary air to the test chamber. The particles will leave the test chamber to a dust collector for dust removal. The instrumentation of the gas and particle flows in the bench-scale cold model will be constructed, and resultant data will be compared with results from the existing exploratory 6 " I.D. cold model.

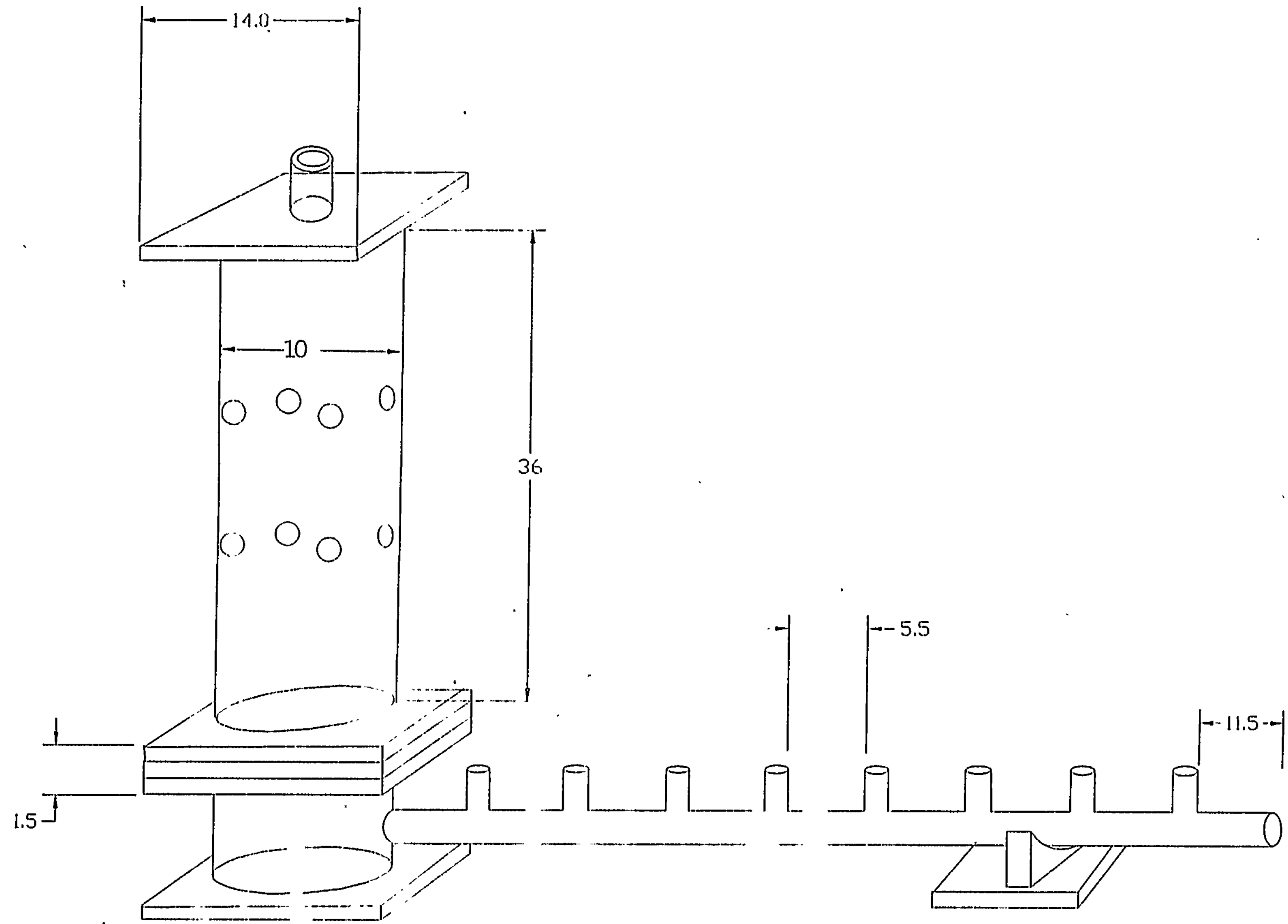

Figure 2 Configuration of the Test Chamber of the Exploratory Cold Model
(All dimensions in inches)

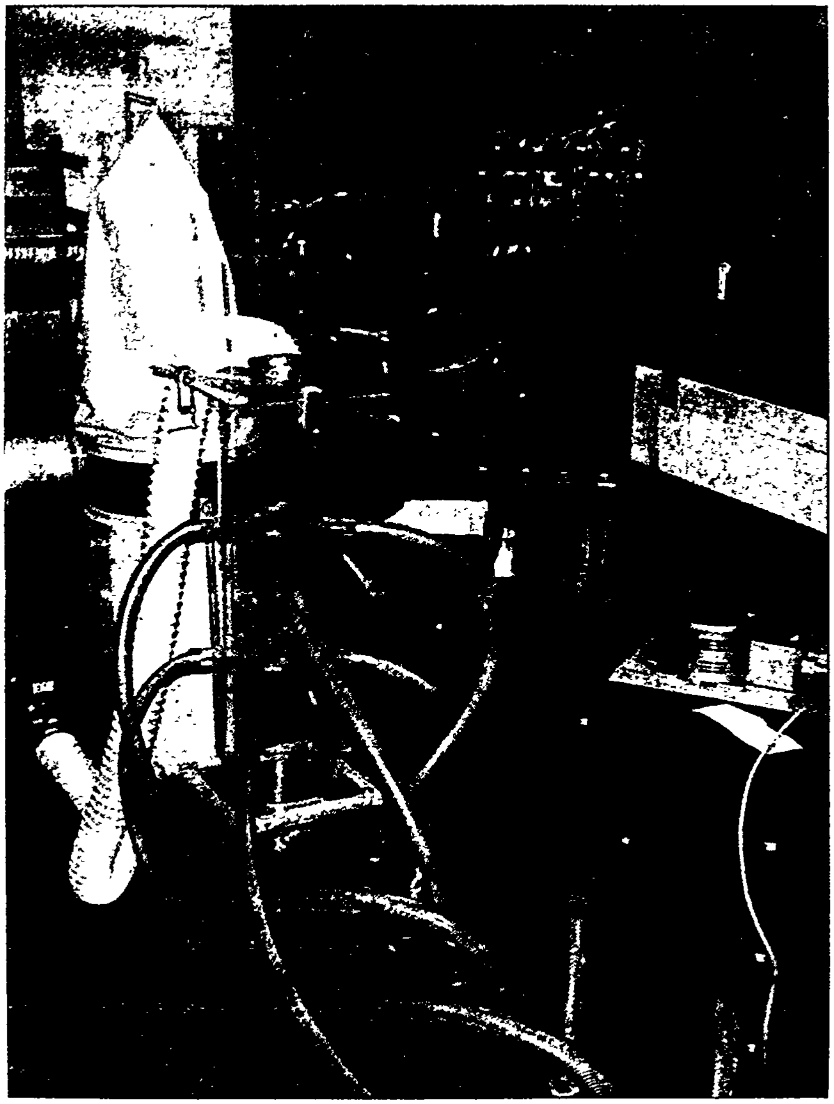

Figure 3 Photograph of the Bench-scale Test Model

SECTION 3

Research Continuation

The progress of this project has been on schedule. The measurements of gas flow in the bench-scale model will be conducted and discussed in the next progress report.

REFERENCES

[1] Lee, S.W. , Technical Progress Report, No. 6 to U.S. DOE PETC, April 1995

[2] Lin, J.S. et al. A Novel Radioactive Particle Tracking Facility for Measurement of Solid Motion in Gas Fluidized Bed, AICHE J. V.31, No.3, pp.465-473, 1985.

[3] Hestroni, G., Handbook of Multiphase Systems, McGraw-Hill Book Co. Chapter 3. 1982.