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Technical Progress Report No.8

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

to

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for

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by

Dr. Seong W. Lee, Principal investigator

Morgan State University
School of Engineering
Baltimore, MD 21239
(phone) 410-319-3137

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SUMMARY

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

The measurements of gas flow in the bench-scale advanced FBC test chamber (10" I.D.) was conducted to better understand and utilize the fluid dynamics of gas and particle flows in the advanced FBC. A 3-dimensional directional probe was used for the measurements of the gas velocity and pressure. A pressure transducer and computer-assisted data acquisition system were employed to measure pressure fluctuations in the freeboard of test chamber.

The test results show that the secondary air flow rate at the lower section affects the gas flow pattern in the test chamber by closing the upper four air nozzles. Also a stronger vortex flow circulation was formed between the center and near the wall region in the vertical direction. The other test results show that a large size of swirl pool above the nozzles was formed between the center and near the wall region in the vertical direction. These results indicate that the vigorous turbulence, such as swirling, recirculating, and developing gas-particle flow with intensified mixing and slip motion can contribute to intensification of the heat/mass transfer and large firing intensity, and high combustion efficiency. The gas/particle flow measurements will be continued in the freeboard of test chamber with an improved computer-assisted data acquisition system. Mathematical modeling/simulation on gas/particle flow will be performed to compare with the experimental results and numerical data.

SECTION 1

Design and Fabrication of Bench-Scale Cold Model

In order to better understand and utilize the fluid dynamics of gas and particle flows in the advanced FBC, a 10 " I.D. bench-scale model [1] was designed, fabricated, and assembled. This model was made of Plexiglas to facilitate visual observations was tested at room temperature without reactions or combustion.

1.1 Experimental Apparatus and Instrumentation

The bench-scale cold model of 10" I.D. is shown in Figure 1. The primary air supply was connected to the bottom of the chamber. There are two sets of secondary air injection with two blowers. Each has four nozzles equally-spaced on the circumferential wall. An exhaust draft fan with dust collector was installed and connected to the top of the combination chamber. With the exhaust draft fan and a bypass controlling valve, the chamber pressure was controlled to keep a constant pressure level.

Three pressure taps were installed on the system. One of them was inserted at the bottom wind chamber to measure the total pressure of primary air. The second tap was inserted at the main frame pipe of the nozzle injectors for measuring the total pressure of the secondary air. The third one was put on the top the of combination chamber to measure the static pressure in the chamber. A Pitot static probe was installed on the exhaust pipe to measure the total air flow rate through the system. A DA &

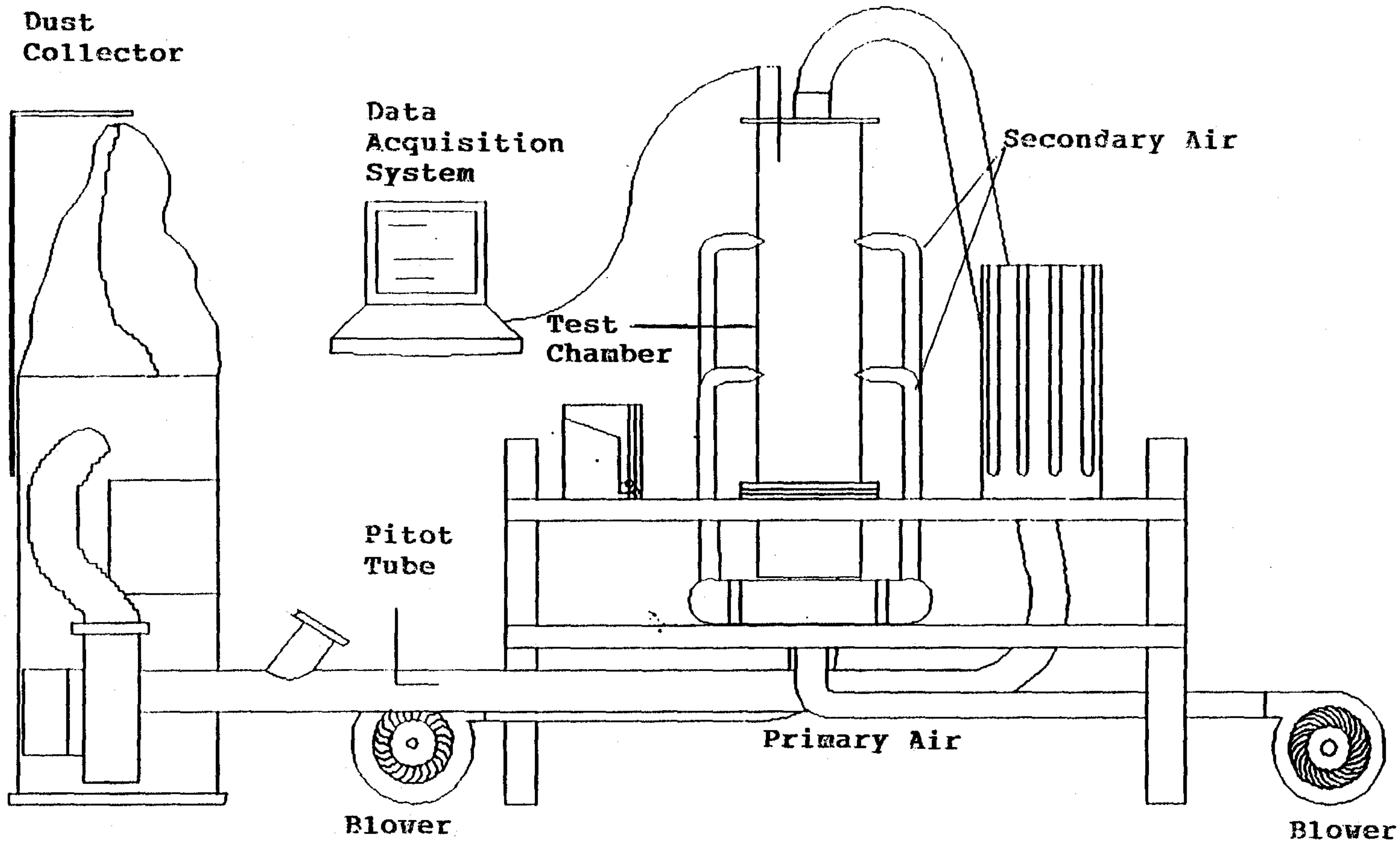


Figure 1 Schematic Diagram of the Bench-Scale Advanced FBC Cold Model System

DAT 3-dimensional directional probe [2] was used for the measurements of gas velocity and pressure.

A differential pressure transducer and the computer-assisted data acquisition system [3] were employed to measure pressure fluctuations in the freeboard of the test chamber. The differential pressure gage, P305D of Validyne Engineering Corp. was connected to the excitation power supply. The output is 5 VDC for full scale of 0.08 psi and 0.2 psi. The analog signal is sent to the Analog Digital Converter (ADC) board, RTI800 of the Analog Devices, Inc. This ADC board converts the analog signal into a digital signal to be recognized and analyzed by a PC computer. The fundamental frequency of the pressure fluctuation, the time average size, motion speed of gas bubble and solid cluster can be determined.

SECTION 2

Measurements of Gas Flow Field

Measurements of gas flow were conducted in the bench-scale (10" I.D.) to better understand how gas recirculating flow is affected by swirling flow in the freeboard of the test chamber.

2.1 Test Conditions

The tests were carried out under two different operating conditions by changing the secondary air flow rate, but with a constant primary flow rate 2.55 ft/s. In the first case, the upper four nozzles were closed and the lower four nozzles were fully opened. In the second case, the upper nozzles were fully opened and the lower four nozzles were closed. The gas velocity at the nozzle outlet for both cases was 76.5 ft/s.

2.2 Test Results and Discussion

The flow characteristics profiles with three direction components, vertical velocity (Z-direction), radial velocity (R-direction), and tangential velocity (Q-direction) were measured. The test results for the first case are shown in Figures 2.2 to 2.4. These results showed that the secondary air flow rate at the lower section affects on the gas flow pattern in the test chamber by closing the upper four air nozzles and fully opening the four lower secondary nozzles. In this case, a large tangential velocity, about 55 ft/s, and a large vertical velocity, 22 ft/s were found out rounding the lower nozzles. Also a stronger vortex flow circulation was formed between the center and near the wall region in the vertical direction. A large tangential velocity occurred at the top center since the top cover forced the air flow into the center exit duct, which had a similar diameter to that of the combustor. The static pressure changed in the Z-direction with about a 0.2 inch water fluctuation.

Figures 3.1 to 3.4 show the effect of the secondary air flow rate at the upper section on the gas pattern in the free-board of test chamber. Thus conduction was made possible by closing the lower four secondary air nozzles and fully opening four upper secondary nozzles. In this case, a large tangential velocity, about 75 ft/s, was found around the upper nozzles. A large size of swirl pool above the nozzles was formed between the center and near the wall region in the vertical direction. The circulating flow was rather stable with a near zero radial velocity and small relative pressure fluctuations.

At the lower section of the combustion chamber, there was another large size vortex flow down the near the wall, then into the center at the bottom, and then up at the center region. The relative static pressure fluctuation was small in the middle section of the chamber, increasing to both ends of the top and bottom. These results indicate that the vigorous turbulence, such as swirling, recirculating, and developing gas-particle flows with intensified mixing and slip motion can be contributed to intensify the heat/mass transfer and large firing intensity, and high combustion efficiency [4].

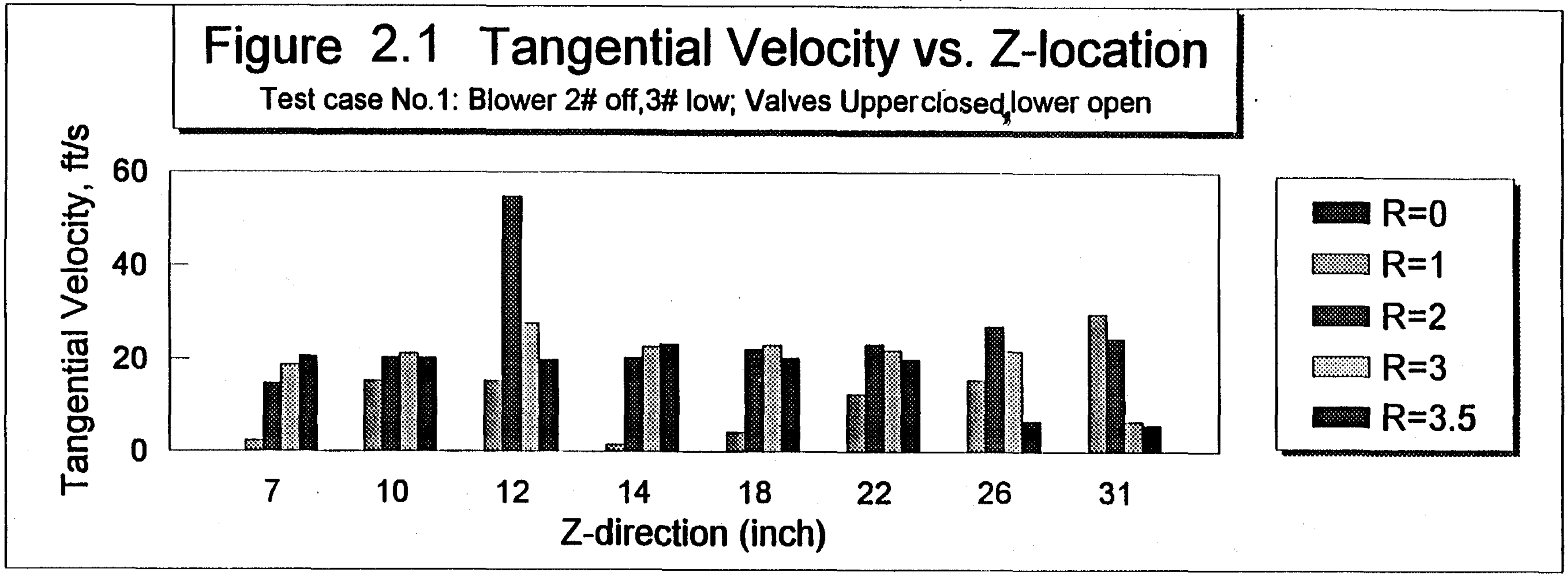


Figure 2.1 Tangential Velocity vs. Z-location
Test case No.1: Blower 2# off,3# low; Valves Upper closed, lower open

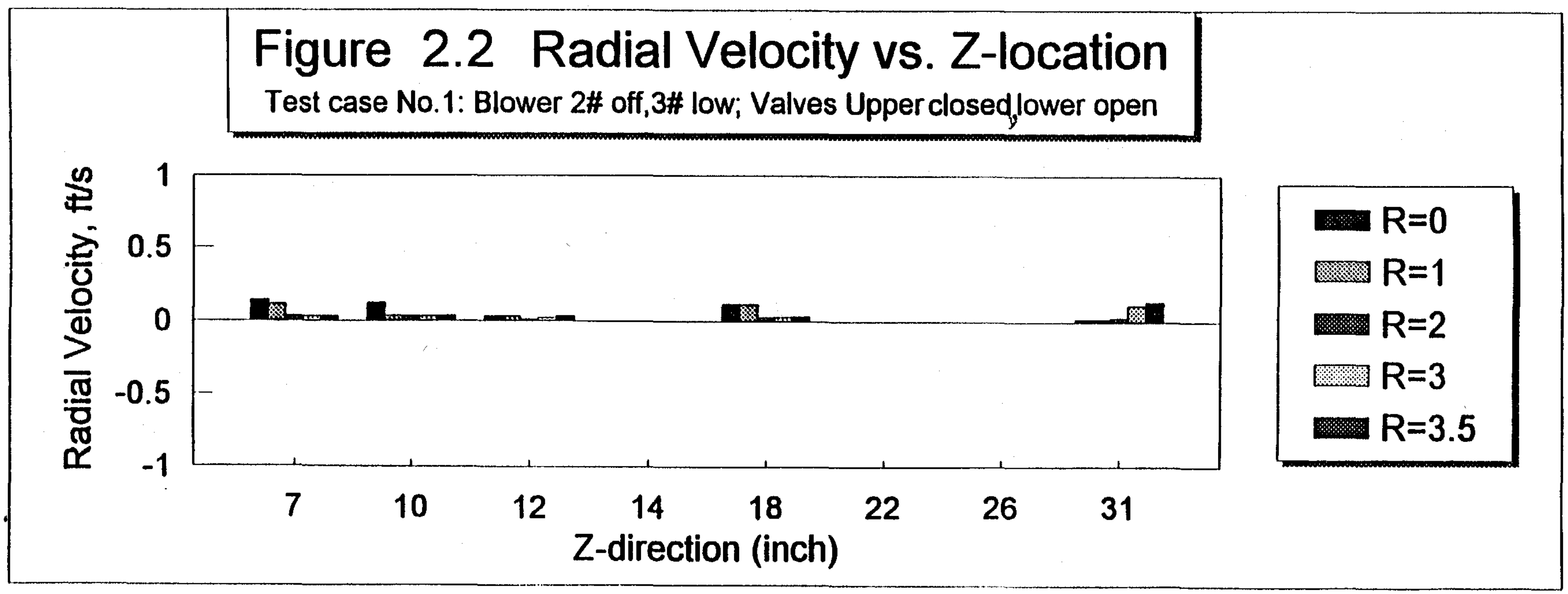


Figure 2.2 Radial Velocity vs. Z-location
Test case No.1: Blower 2# off,3# low; Valves Upper closed, lower open

Figure 2.3 Vertical Velocity vs. Z-location

Test case No.1: Blower 2# off,3# low; Valves Upper closed, lower open

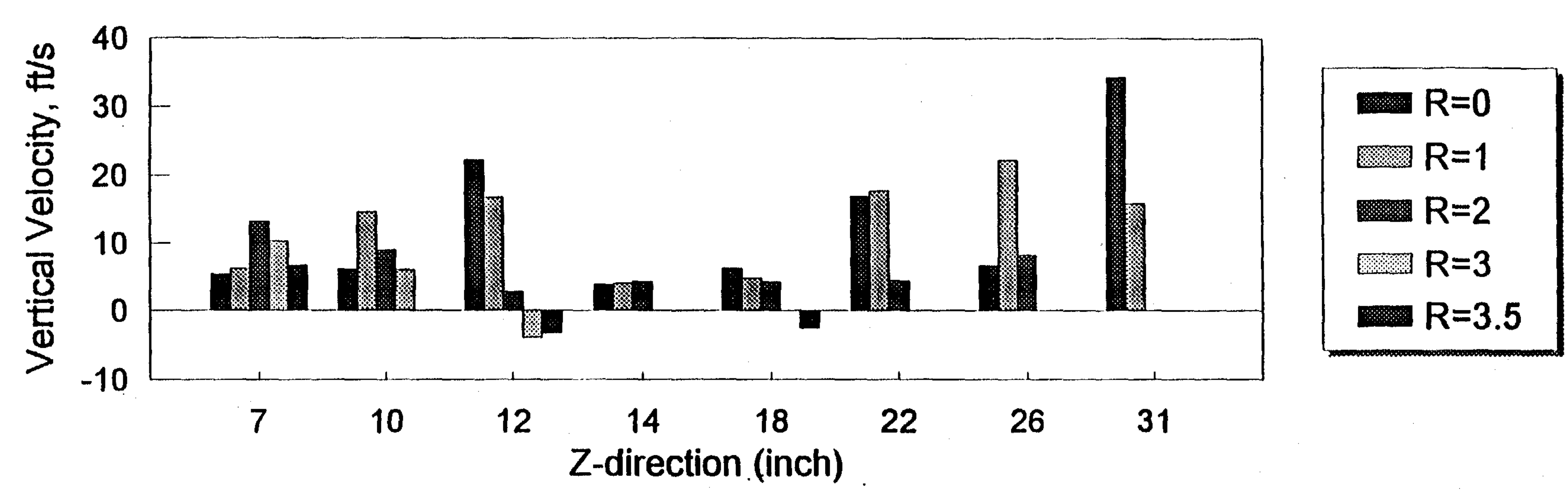


Figure 2.4 Static Pressure Change in Z-direction

Test case No.1: Blower 2# off,3# low; Valves Upper closed, lower open

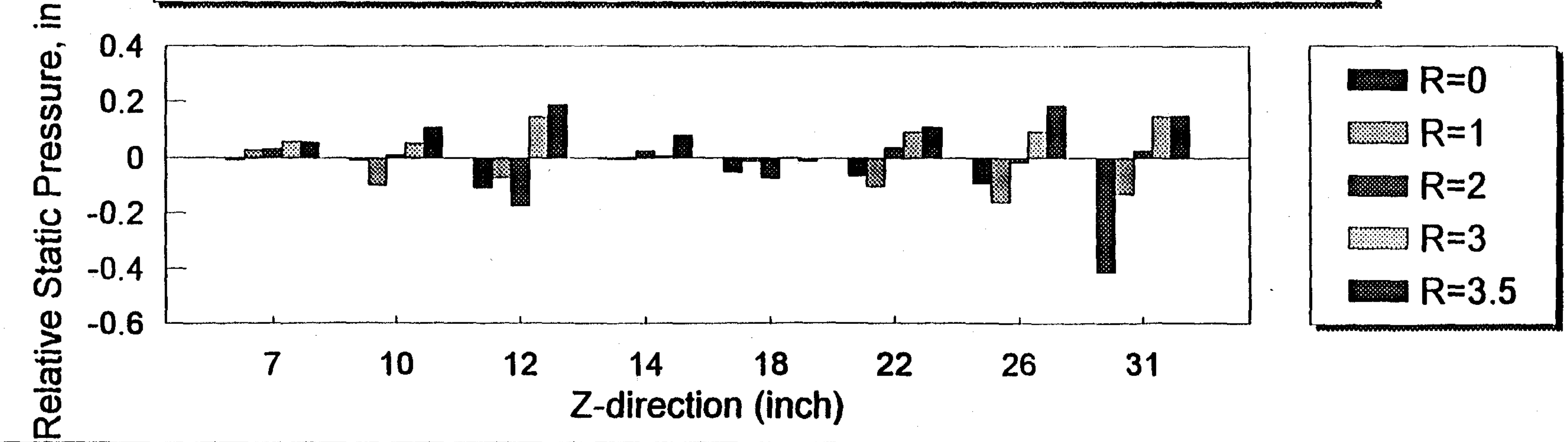


Figure 3.1 Tangential Velocity vs. Z-location

Test case No.2: Blower 2# off,3# low; Valves Upper open, lower closed

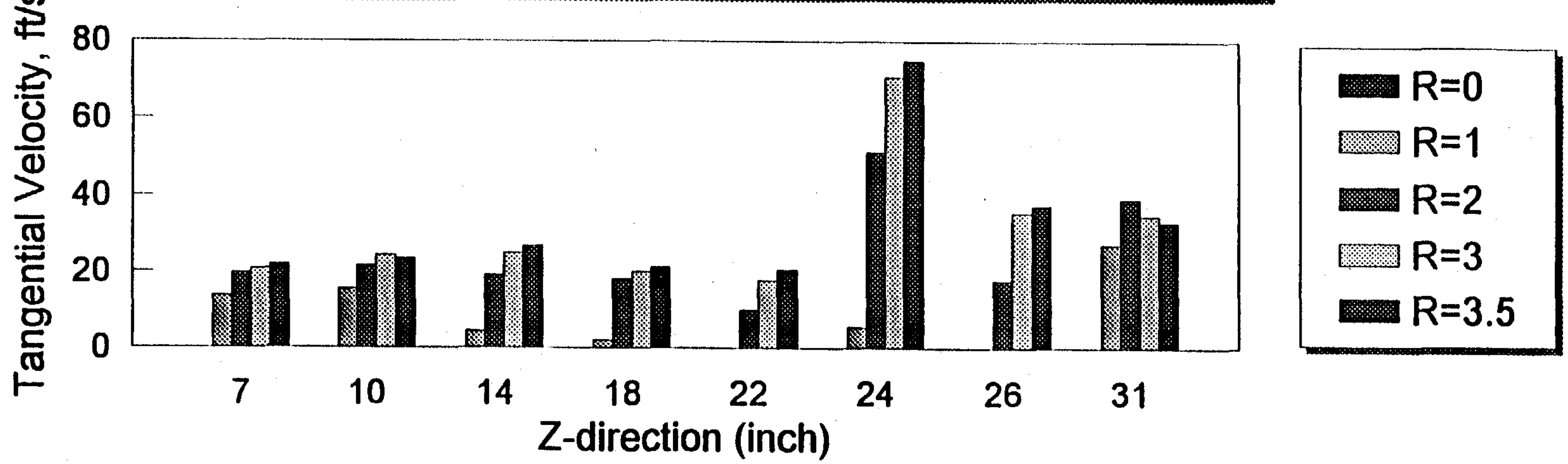


Figure 3.2 Radial Velocity vs. Z-location

Test case No.2: Blower 2# off,3# low; Valves Upper open, lower closed

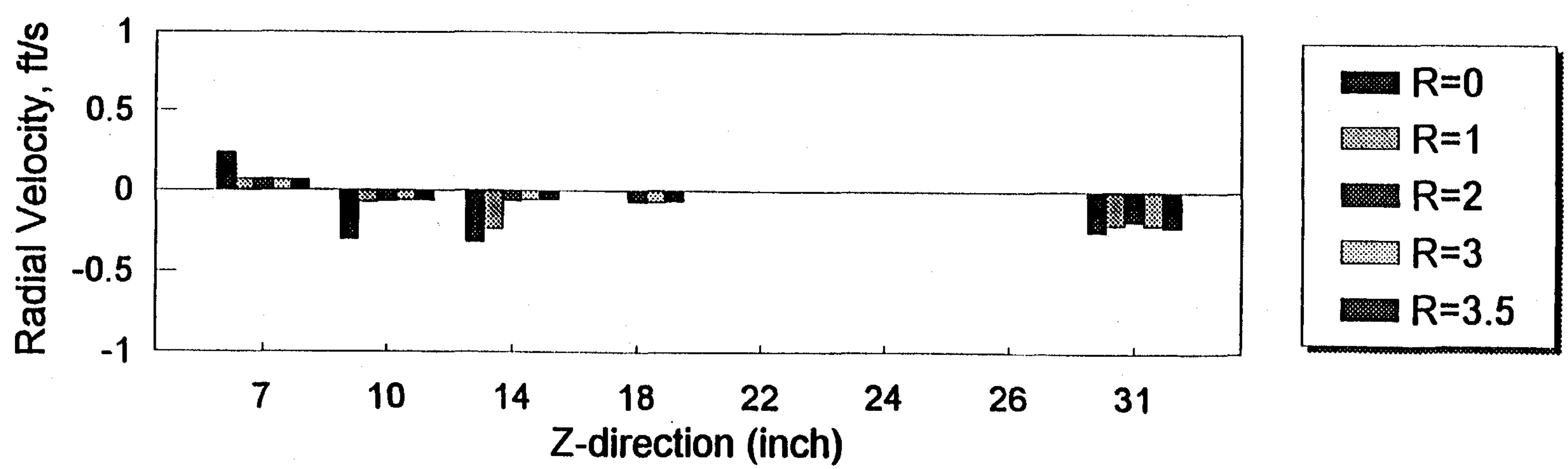


Figure 3.3 Vertical Velocity vs. Z-location

Test case No.2: Blower 2# off,3# low; Valves Upper open, lower closed

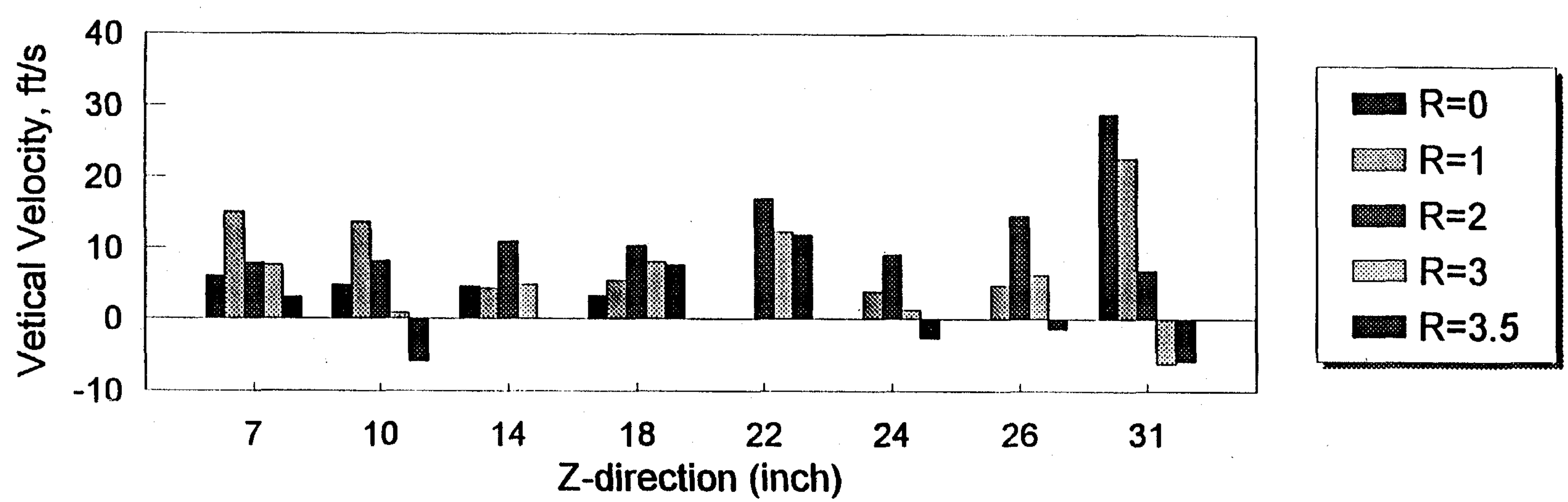
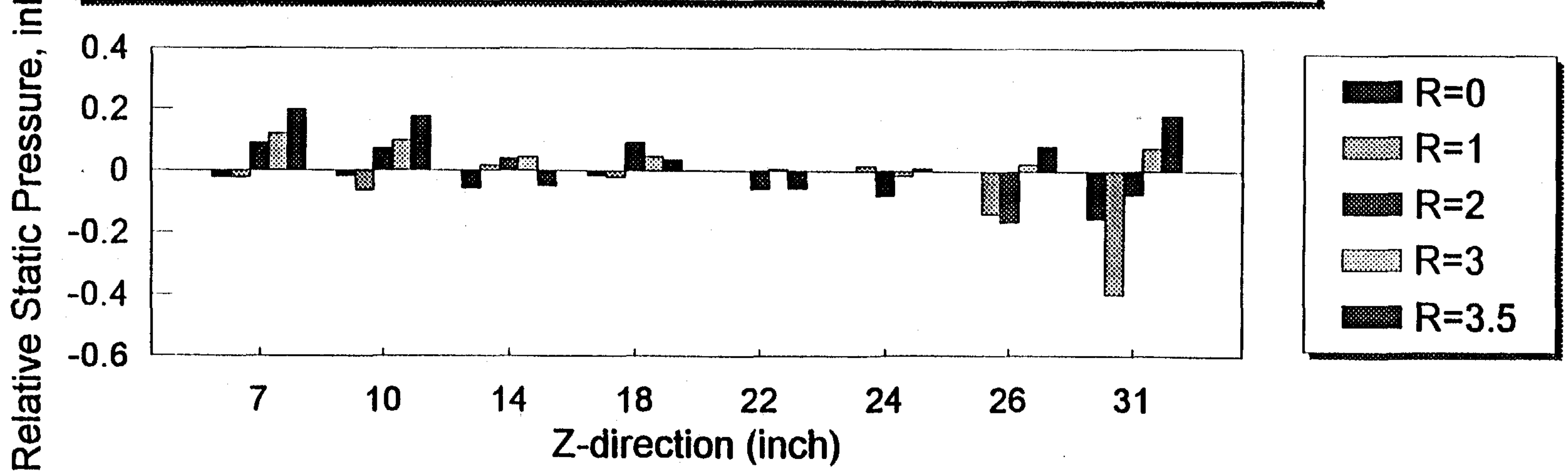


Figure 3.4 Static Pressure Change in Z-direction

Test case No.2: Blower 2# off,3# low; Valves Upper open, lower closed



SECTION 3

Research Continuation

This progress of this project has been on schedule. The gas/particle flow measurements will be continued under different test conditions with an improved computer-assisted data acquisition system. Mathematical modeling/simulation on gas/particle flows will be performed using computational fluid dynamics (CFD) code (Fluent code) to compare with experimental results and numerical data.