DOE/MT/93006--T1

Technical Progress Report No.5

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

to

U.S. Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940, MS 921-118
Pittsburgh, PA 15236-0940

for

Project No: DE-FG22-93MT93006

by

Dr. Seong W. Lee, Principal investigator

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

January 1995

MASTER

# DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

SUMMARY

This technical report summarizes the research work performed and progress achieved during the period of October 1, 1994 to December 31, 1994.

The measurement of gas flow continued with the assumption of axisymmetric flow in the laboratory-scale FBC. The gas axial velocity distributions at two cross-section in the test chamber were presented.

The circulating flow is relatively strong (swirl number of 3.0) near the freeboard wall for the two cross-sections because the flow has high reversal air velocity. The recirculation flow had weak air velocity when the swirl number of 0.60. For the non-swirling flow, the axial velocity was low near the freeboard wall. However, no circulating flow was observed at the two cross-sections.

The measurement of the gas axial velocity will be continued to observe the effect of the secondary air injection angles.

TABLE OF CONTENTS

# SECTION 1

## Measurement of Gas Flow

### 1.1 Axial Velocity Distribution

The measurement of gas flow continued with the assumption of axisymmetric flow in the laboratory-scale FBC [1]. The gas velocity and pressure measuring system consisted of DA&AT 3-dimensional (5-hole directional) probe [2], a universal traverse probe holder, four manometers, and one pressure differential gage.

The gas flow field in the test chamber of the FBC was assumed to axisymmetric. Measurements were made primarily in a vertical plane passing through the chamber axis. Figure 1 shows the gas axial velocity distributions at two cross-sections. Three sets of data from the upper part of the FBC were obtained at a cross-section 3" below the air inlet of the lower-level (designated as section 1), and the other three sets were measured at a cross-section 3" below the location of section 2. The axial locations of the two sections are indicated in the bottom part of Figure 1.

As shown in Figure 1, the circulating flow is relatively strong (swirl number of 3.0) near the freeboard wall for the two cross-sections because the flow has high reversal gas velocity. The recirculation flow had a weak air velocity when the swirl number of 0.60. For the non-swirling flow, the axial velocity was low near the freeboard wall. However, no circulating flow was observed at the two cross-sections.

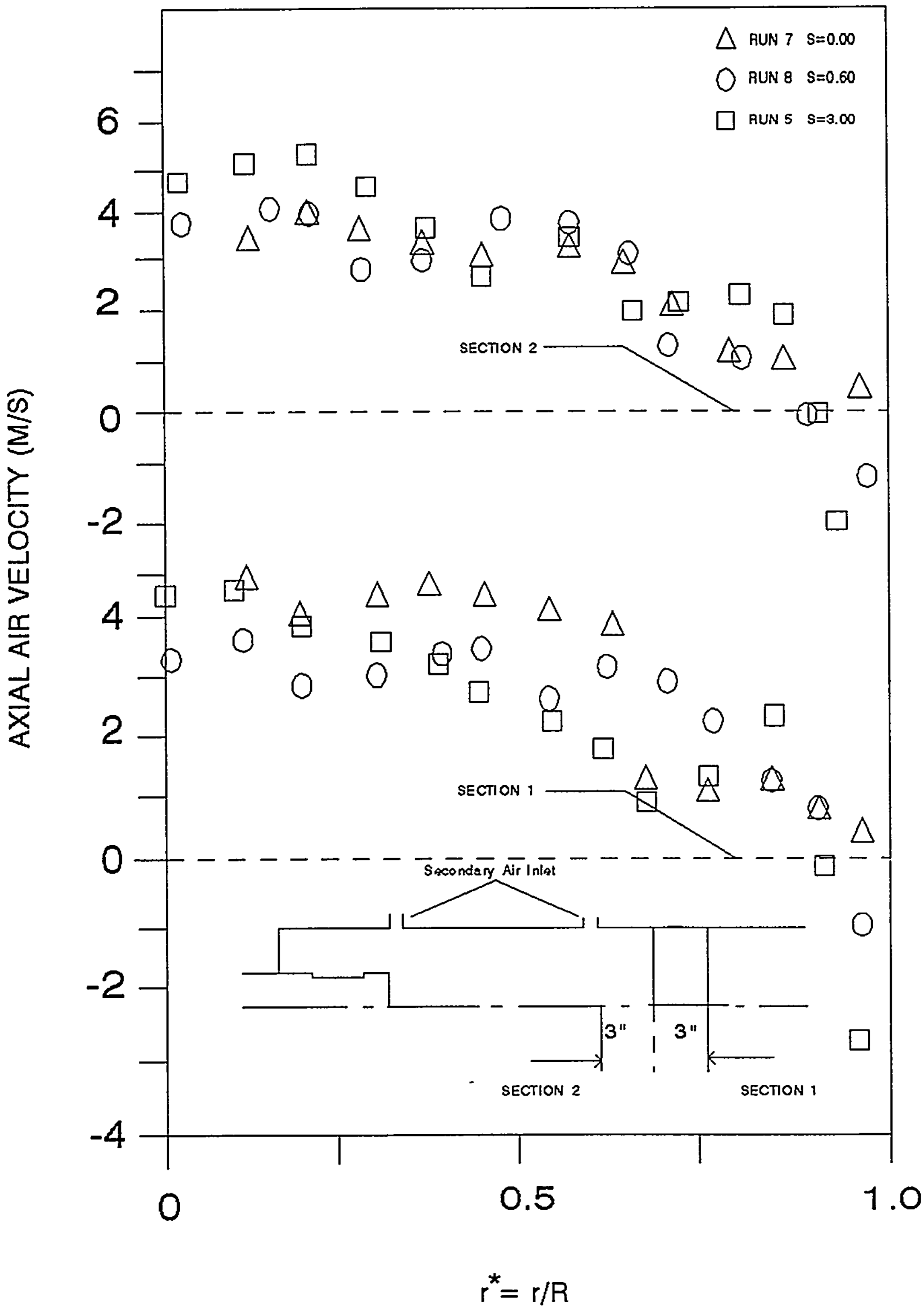


Figure 1 Gas Axial Velocity Distribution affected by Swirl Number

## 1.2 Swirl Number

Strong swirling flow is one of the major features of the advanced fluidized bed combustor. The swirling intensity is dedicated by swirl number S, which is a dimensionless number defined by the ratio of axial flux of angular momentum $G_\theta$ to the axial momentum $G_x$ multiplied by the equivalent chamber radius [3].

$$S = \frac{G_\theta}{G_x \, d/2}$$

where

$$G_\theta = \int_0^\infty (\rho u w + \rho \overline{u'w'}) \, r^2 dr$$

$G_\theta$ includes the x-θ component of the turbulent shear stress.

and

$$G_x = \int_0^\infty (\rho u^2 + \rho \overline{u'^2} \div (p - p_\infty) \, r^2 dr$$

$G_x$ includes the term of turbulent normal stress in x-direction and the pressure term.

It can be deduced that the swirl number S can be approximated as the ratio of gas tangential velocity to axial velocity at the exit section. Generally speaking, the larger the swirl number, the higher the tangential velocity, and hence, the stronger the swirling flow. For cyclonic flows, if assuming a uniform velocity at exit, the swirl number of isothermal flow can be expressed as:

$$S = \frac{\pi D_e D_o}{4A_t}$$

where De and Do are the diameters of the exit throat and the main section of the cyclone chamber, respectively. $A_t$ is the total cross-sectional area of the tangential region. Since the advanced FBC has the unique configuration of multiple inlets and tangential-radial nozzles, the above equation should be modified. The swirl number for the exploratory-scale model of the advanced FBC system can be deduced based upon the original definition of equation, as follows [4]:

$$\text{Swirl Number} = \frac{\text{Inlet Angular Momentum}}{\text{Outlet Axial Momentum} * De/2}$$

$$= \frac{\pi \gamma^2}{4}\left(\frac{D_i D_e}{A_t}\right)$$

where $D_e$ = Diameter of exit tube

$D_i$ = Diameter of imaginary circle of secondary air injection

$D_o$ = Diameter of freeboard

$\beta$ = Injection angle of nozzle

$A_t$ = Total outlet area of secondary air nozzle

$\gamma$ = Volumetric flow rate ratio between secondary air flow and total air flow

It is worth nothing that the swirl number of the FBC is not only dependent on geometric factors but also related with the operating parameters.

## SECTION 2

The progress of this project has been on schedule. The gas axial velocity distribution was measured and presented in the advanced laboratory-scale FBC, which was affected by swirl number. The measurement of the gas axial velocity will be continued to observe the effect of the secondary air injection angles.

## REFERENCES


[1] Lee, S.W., Technical Progress Report, No.4 to U.S. DOE, Pittsburgh Energy Technology Center, October 1994.

[2] Manual of probe Catalog, United Electric Controls Company, Watertown, MA.

[3] Syred, N. and J.M. Beer, Combustion in Swirl Flows:a Review, Combustion and Flame, Vol. 23, pp. 143-201, 1974.

[4] Lee, S.W., Technical Progress Report, No.1 to U.S. DOE, Pittsburgh Energy Technology Center, January 1994.