DOE/PC/30218-T1 MASTER

DE-FG22-80PC30218-1

SCALED-BED MODELING FOR FLUIDIZED-
BED COMBUSTORS

Semi-Annual Report
for the period
October 1, 1980 - March 31, 1981

by

Dr. Thomas J. Fitzgerald
Stephen D. Crane

March 1981

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Work Performed Under Contract

DE-FG22-80PC30218

by

Department of Chemical Engineering
Oregon State University
Corvallis, OR 97331

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

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

SCALED BED MODELING FOR FLUIDIZED
BED COMBUSTORS

Semi-Annual Report
for the period
October 1, 1980 - March 31, 1981

by

Dr. Thomas J. Fitzgerald
Stephen D. Crane

March 1981

Work Performed Under Contract
DE-FG22-80PC30218

by

Department of Chemical Engineering
Oregon State University
Corvallis, OR 97331

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This technical report is being transmitted in advance of DOE patent clearance and no further dissemination or publication shall be made of the report without prior approval of the DOE Patent Counsel.

This technical report is being transmitted in advance of DOE review and no further dissemination or publication shall be made of the report without prior approval of the DOE Project/Program Manager.

TABLE OF CONTENTS

	<u>PAGE</u>
DISTRIBUTION LIST	i
INTRODUCTION	1
BACKGROUND	1
PROCEDURE	2
ACCOMPLISHMENTS	4
APPENDIX	7

*Conf Paper - removed & Cycled
separately - op 5/6/81*

DISTRIBUTION LIST

	<u># Copies</u>
Richard Rogus Contract Specialist Acquisition & Assistance Division Pittsburgh Energy Technology Center U.S. Department of Energy P.O. Box 10940 Pittsburgh, PA 15236	1
Marilyn Keane Administrative Assistant University Contracts Management Division Pittsburgh Energy Technology Center U.S. Department of Energy P.O. Box 10940 Pittsburgh, PA 15236	3
U.S. Department of Energy Chicago Operations & Regional Office Patents Division 9800 South Cass Avenue Argonne, IL 60439	1
Technical Information Center Special Assistant for Reproduction & Processing U.S. Department of Energy P.O. Box 62 Oak Ridge, TN 37830	1
Holmes Webb Technical Project Officer Morgantown Energy Technology Center P.O. Box 880 Morgantown, WV 26505	1
Fred W. Steffgen Program Officer U.S. Department of Energy PETC University Contracts Management Division P.O. Box 10940 Pittsburgh, PA 15236	4
Louis J. Ruzzi Grants Officer U.S. Department of Energy PETC University Contracts Management Division P.O. Box 10940 Pittsburgh, PA 15236	2

INTRODUCTION

Fluidized bed coal combustion may become an important method for generating power with minimal pollution. The low temperature involved prevents the formation of nitrogen oxides, and the crushed limestone bed material scavenges sulfur dioxide as it is formed. Heat transfer coefficients to immersed steam tubes in a fluidized bed boiler are quite high, allowing compact boiler design. And fuel utilization is good if elutriated fines are recycled back into the combustor. All these things have been demonstrated in existing pilot plant units.

But at present, there is no well established method for scaling pilot plants up to practical size. Experience with fluidized beds in the chemical process industries suggests that scaling up is a difficult problem. Large beds have different solids circulation and solids-gas contacting patterns than small beds, and a unit which performs well at the pilot scale often falls well below expectations at full scale.

BACKGROUND

A simplified hydrodynamic description of fluidized bed hydrodynamics leads to the conclusion that the bed performance depends on bed geometry and four dimensionless ratios:

1. The ratio of particle size to a characteristic bed dimension.
2. The ratio of particle form drag to gravitational force.
3. The ratio of viscous forces on a particle to the inertial forces on the particle.
4. The ratio of gas density to solids density.

If these ratios have the same numerical value in two geometrically similar beds of otherwise different properties (for instance, different size, different

density, different gas viscosity) then according to theory both beds are hydrodynamically similar: if motion pictures are taken of both beds, and played back with appropriate size and time scaling, both beds should look alike.

Previous experimental studies (Fitzgerald, Crane, 1980) using motion pictures to compare the behavior of paired fluidized beds which were scaled according to theory have been conducted. The motion pictures revealed similar behavior patterns in each of the beds. In addition, analysis of the spectral densities of the pressure fluctuations across the beds also showed many similarities.

These preliminary results indicate that the four dimensionless groups can be used for scaling cold models. The ongoing research effort will carry these findings further to determine if the use of dimensionless groups is a viable method of predicting the hydrodynamics of large hot fluidized beds by measurements made of smaller room temperature fluidized bed scale models.

The technique could be used for predicting solid circulation and gas-solid contacting patterns in large beds and would enable the results from pilot scale units to be used with confidence in predicting the performance of full scale units.

PROCEDURE

Comparisons will be made between a 1.83 m by 1.83 m hot atmospheric pressure fluidized bed combustor and a 45.7 cm by 45.7 cm cold (ambient temperature) atmospheric pressure 1/4 scaled model. The hot AFBC will be fluidized by air and combustion gases at 850°C, with limestone and coal bed media, and 5 cm diameter heat exchange tubes. The cold AFBC 1/4 scaled model will be fluidized by air at 30°C, with copper bed media and 1.25 cm dummy heat exchange tubes. The values of the afore-mentioned dimensionless groups will be identical for both cases, that is,

$$\frac{\rho_s}{\rho_g} \text{ hot} = \frac{\rho_s}{\rho_g} \text{ cold}$$

where: ρ_s = solids density and ρ_g = gas density,

$$\frac{d_p}{L} \text{ hot} = \frac{d_p}{L} \text{ cold}$$

where: d_p = bed media particle size and L = a characteristic bed dimension,

$$\frac{U^2}{Lg} \text{ hot} = \frac{U^2}{Lg} \text{ cold}$$

where: U = superficial gas velocity and g = acceleration of gravity, and

$$\frac{d_p U \rho_g}{\mu_g} \text{ hot} = \frac{d_p U \rho_g}{\mu_g} \text{ cold, the particle Reynold's Number}$$

where: μ_g = the kinematic viscosity of the gas.

In a second comparison a thin cross section 48.3 cm by 12.7 cm cold bed at 1.6 atmospheres and fluidized by helium, with 2.5 cm diameter dummy heat exchange tubes and reacted limestone bed media will be compared to a thin cross section cold bed 24.2 cm by 6.4 cm, fluidized by air at atmospheric pressure with 1.25 cm dummy heat exchange tubes and copper bed media. The dimensionless numbers will again be set to the same value. Movies of both systems will be taken for each experimental condition and the film speed will be adjusted to account for the differences in time scales. The movies of each configuration should show similarities in bubble growth and bubble rise velocities and solids flow patterns. In addition, pressure measurements will be made across all of the beds at one superficial gas velocity for the 6 foot by 6 foot hot bed and at U_{mf} and various multiples of U_{mf} for the other beds. The data will be analyzed using a fast Fourier transform power spectrum to determine the frequency

of the pressure fluctuations. The ratio of the average frequencies should be equal to the velocity/time scaling factor.

ACCOMPLISHMENTS

Construction of the thin cross section 48.3 cm bed is approximately 2/3 complete. Final assembly of the doors and tube array should be completed near the end of April. Pressure testing and debugging of the system will commence around May 1, 1981 and data collection should begin around June 1, 1981. All necessary components have arrived or are in transit.

The construction of the 45.7 cm 1/4 scaled model is nearly 3/4 complete. All components have been fabricated and assembly has commenced.

The pressure transducers and associated electronics and computer programs have been tested and calibrated.

Pressure data has been collected from the Babcock and Wilcox 1.83 m by 1.83 m hot atmospheric fluidized bed combustor located in Alliance, Ohio. The analysis of the data is just beginning and therefore will not be included in this report. Movies were not taken because the top of the bed media could not be seen from the view port. However, enough data was collected to make the necessary comparisons between the hot and cold systems.

Figure 1: Diagram of the 48.3 cm by 12.7 cm (19 inch by 5 inch) thin cross section cold fluidized bed using helium at 1.6 atmospheres and ambient temperature as the fluidizing gas.

Figure 2: Diagram of the 45.7 cm by 45.7 cm (18 inch by 18 inch) fluidized bed using air at atmospheric pressure and ambient temperature as the fluidizing gas.