DOE/PC/94223--T4

QUARTERLY REPORT

FOR

GRANT NO. DE-FG22-94PC94223

ENTITLED

"ADVANCED COMBUSTOR DESIGN CONCEPTS
TO CONTROL NOX AND AIR TOXICS"

SUBMITTED BY

COLLEGE OF ENGINEERING

UNIVERSITY OF UTAH

DR. DAVID W. PERSHING

DR. JOANN LIGHTY

JENNIFER SPINTI

OCTOBER 31, 1995

RECEIVED
USDOE/PETC
95 NOV 13 AM 10:17
TECHNICAL & ASSISTANCE DIV.

US/DOE PATENT CLEARANCE IS NOT REQUIRED PRIOR
TO THE PUBLICATION OF THIS DOCUMENT

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.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

HH

MASTER

1.0 Program Overview

Direct coal combustion must be a primary energy source for the electric utility industry and for heavy manufacturing during the next several decades because of the availability and economic advantage of coal relative to other fuels and because of the time required to product major market penetration in the energy field. However, the major obstacle to coal utilization is a set of ever-tightening environmental regulations at both the federal and local level. It is, therefore, critical that fundamental research be conducted to support the development of low-emission, high efficiency pulverized coal power systems.

The University of Utah, Massachusetts Institute of Technology (MIT), Reaction Engineering International (REI) and ABB/Combustion Engineering have joined together in this research proposal to develop fundamental understanding regarding the impact of fuel and combustion changes on ignition stability and flame characteristics because these critically affect: NO_x emissions, carbon burnout, and emissions of air toxics. Existing laboratory and bench scale facilities are being used to generate critical missing data which will be used to improve the NO_x and carbon burnout submodels in comprehensive combustion simulation tools currently being used by industrial boiler manufacturers. To ensure effective and timely transfer of this technology, a major manufacturer (ABB) and a combustion model supplier (REI) have been included as part of the team from the early conception of the proposal.

ABB/Combustion Engineering is providing needed fundamental data on the extent of volatile evolution from commercial coals as well as background information on current design needs in industrial practice. Since they will ultimately be a recipient of the enhanced design methodology, they are also providing ongoing review of the practical applicability of the tools being developed. MIT is responsible for the development of an improved char nitrogen oxidation model which will ultimately be incorporated into an enhanced NO_x submodel. Reaction Engineering International is providing the lead engineering staff for the experimental studies and an overall industrial focus for the work based on their use of the combustion simulation tools for a wide variety of industries. The University of Utah is conducting bench scale experimentation to (1) investigate alternative methods for enhancing flame stability to reduce NO_x emissions and (2) characterize air toxic emissions under ultra-low NO_x conditions because it is possible that such conditions will alter the fate of volatile and semivolatile metal species and the emission of heavy hydrocarbons. Finally the University of Utah is responsible for the development of the improved NO_x and carbon burnout submodels.

2.0 Progress During The Last Quarter

2.1 Char Collection System

In order to develop improved NO_x and carbon burnout submodels, experimental data is required from coal chars. As described in the quarterly report for the quarter ending 6/95, a char collection system has been installed on the U furnace located at the University of Utah. This char collection system was designed to collect char from a premixed pulverized coal flame in the U furnace. It has been used successfully to collect chars from four different coals.

Collecting partially burned coal chars proved to be a very challenging task. The original system design (as seen in the quarterly report for the quarter ending 6/95) was modified slightly after initial tests to improve char collection rates. The redesigned char collection system is sketched in Figure 1. One of the changes was the replacement of the water-cooled diversion plate with a piece of rigid, high temperature insulation. The purpose of the plate and later the insulation was to block off the rest of the furnace so that burning coal particles were forced into the cooling section of the char collection system. The water-cooled plate was replaced due to excessive ash buildup on the plate. A second change was the addition of a third cooling section between the furnace port and the cyclone. This addition was necessary to maintain cyclone temperatures below 1200F. A third change was the addition of an air-assisted water spray nozzle mounted to the sample port through which the flue gas exits the furnace. This nozzle also served to reduce inlet temperatures at the cyclone and to more effectively quench char oxidation. Finally, the flow measurement system (a pitot tube-type device) was removed due to damage from the high temperature flue gas stream. Instead of using flow sensors to monitor the process, furnace pressure upstream of the char collection system was monitored. A bypass valve to the vacuum pump was adjusted to maintain furnace pressure near zero (± 0.10 inches H_2O).

The char collection system was initially set up in the second port in the U furnace. However, early tests burning a Utah bituminous coal showed that oxygen levels were down below 5% at this port, indicating nearly complete burnout. Since it was desired to obtain chars which were only partially oxidized, the whole system was moved to the first available port in the furnace, which is located approximately 18 inches below the burner. All chars subsequently discussed were obtained from the first port.

A total of five different coals were burned and their chars collected. Three coals exhibited good ignition and flame stability properties and were also relatively easy to feed. These coals were the Utah bituminous, Illinois No. 6, and Pittsburgh No. 8 coals. The other two coals, Black Thunder subbituminous and Knife River Beulah Zap lignite, proved to be so wet and sticky that feeding was extremely difficult and flame stability could only be maintained by burning the coal with natural gas (20-50% of the energy input). To eliminate these problems, approximately 150 pounds of Knife River coal were dried for 4 hours at 150F. This dried coal was much easier to feed and flame stability was good without any natural gas injection.

Three different methods were used in the char collection system for cooling the flue gas and quenching char oxidation. In the first method, air was injected through the dilution gas injector. This air blew across the insulation (used for diversion) and cooled the flue gas as it exited the furnace. In the second method, nitrogen was injected instead of air. The third method was a combination of air injection and the water spray nozzle mounted to the sample port.

Data from all the char collection experiments performed are presented in Tables I, II and III below. Data include carbon, hydrogen, nitrogen and ash analysis and an estimated burnout based on ash content. Considering both percent burnout and the amount of char collected, the least effective method of quenching char oxidation was air injection. Both nitrogen injection and air injection with water spray produced higher yields of char that were less burned out. Char collection rates were excellent for both the Utah bituminous and Pittsburgh No. 8 coals and good for the Illinois No. 6 coal. However, char collection rates were poor for the Knife River coal, necessitating long run times.

Sample Name	%C	%H	%N	%Ash	% Burnout
Pitt No. 8, 25sept95	59.47	0.38	0.89	38.36	83.51%
Pitt No. 8, 26sept95	62.63	0.465	1.005	34.39	80.62%
Pitt No. 8, 29sept95 (#2)	66.63	0.44	1.065	30.68	76.89%
III No. 6, 14sept95	64.38	0.193	1.15	34.43	85.67%
III No. 6, 18sept95	76.32	1.235	1.515	16.98	65.56%
III No. 6, 19sept95	63.14	0.18	1.01	35.86	86.51%
III No. 6, 20sept95	66.75	0.28	1.28	31.06	83.53%
III No. 6, 21sept95	65.36	0.345	1.205	31.88	84.29%
III No. 6, 22sept95	69	0.373	1.277	27.17	80.54%
Utah Bit. #1	59.85	0.325	0.955	36.93	80.88%
Utah Bit. #2	58.37	0.545	0.965	34.91	80.28%
Utah Bit., 13sept95	63.82	0.61	1.037	31.59	76.17%

Table I
Quenching with Air

Sample Name	%C	%H	%N	%Ash	% Burnout
Pitt No. 8, 27sept95	69.54	0.43	1.16	27.13	72.73%
Pitt No. 8, 28sept95	69.07	0.5	1.135	27.72	73.49%
Pitt No. 8, 29sept95 (#1)	71.32	0.33	1.09	26.05	70.87%
Knife River, 9&11oct95	29.25	0.215	0.42	71.22	91.62%
Knife River, 29oct95	54.13	0.813	0.768	39.88	72.30%
Knife River, 30oct95	49.75	0.465	0.72	47.5	78.63%
III No. 6, 12oct95	61.25	0.21	0.99	37.53	87.49%
III No. 6, 13oct95	65.29	0.403	1.1	31.42	84.08%
III No. 6, 16oct95	71.1	0.21	1.11	27.43	80.14%
Black Thunder	37.1	0.165	0.49	60.52	94.36%

Table II
Quenching with Nitrogen

Sample Name	%C	%H	%N	%Ash	% Burnout
Knife River, 26oct95	46.06	0.555	0.57	49.41	80.98%
Knife River, 31oct95 (#1)	55.9	0.245	0.62	42.5	73.16%
Knife River, 31oct95 (#2)	49.71	0.925	0.585	44.59	77.25%
Knife River, 1nov95	53.88	0.805	0.57	40.05	72.55%
Pitt No. 8, 19oct95 (#1)	61.27	0.225	0.8	35.9	81.84%
Pitt No. 8, 19oct95 (#2)	65.86	0.905	1.095	29.99	76.64%
Pitt No. 8, 24oct95	63.23	0.695	0.82	30.95	78.27%

Table III
Quenching with Air and Water Spray Nozzle

These data indicate that we now have a suite of coal chars of varying types and levels of burnout for use in subsequent experimental studies. Despite the many difficulties encountered, the char collection phase of the program was a success. Chars were obtained from coals burned at actual pulverized coal operating conditions, so data from these chars should accurately reflect what is happening in a pulverized coal furnace.

3.0 Plans for Next Quarter

The collected chars will be analyzed in more detail and sized, and then experiments will begin using these chars. Data from these experiments will provide insight into NO_x formation from char nitrogen and will aid in further NO_x submodel development.

Figure 1