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## COMBUSTION CHARACTERIZATION OF COAL FINES RECOVERED FROM THE HANDLING PLANT

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By:

Masudi, Houshang; Principal Investigator  
Samudrala, Surender Rao; Graduate Research Assistant  
Reid, Elna; Undergraduate Research Assistant

S. N. Dwivedi; Project Consultant

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## **ABSTRACT**

The main goal of this research project is to evaluate the combustion characteristics of the slurry fuels prepared from the recovered coal fines and plant coal fines. A specific study was completed which collected data on combustion behavior, flame stability, ash behavior, emissions of  $\text{SO}_2$  and  $\text{NO}_x$ , and particulate in a well insulated laboratory scale furnace. In addition, the residence time and temperature history of the burning particles are similar to that of the utility boiler furnace at 834,330 Btu/hr input at an average of 15% excess air. The slurry fuel was prepared at 53.5% solids to match the generic slurry properties. The coal blend was prepared using a mixture of 15% wet milled pond fines and 85% plant fines. Combustion characteristics of the slurry fuels were determined at three different firing rates: 834,330 Btu/hr, 669,488 Btu/hr and 508,215 Btu/hr. Finally, a comparison of the results will be developed for determining the advantages of coal-water slurry fuel over the plant blend form.

## **OBJECTIVES**

The main objective of this project is to determine the combustion characteristics of coal-water slurry fuel prepared from the recovered coal fines and plant coal fine fractions.

The specific goals of the project are:

- Preparation of a stable coal-water slurry fuel and evaluation of its rheological properties.
- Determination of the flame stability characteristics
- Evaluation of the combustion efficiency
- Evaluation of the fuel's fouling potential
- Examination of emissions of  $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{CO}$ ,  $\text{CO}_2$ , and  $\text{O}_2$
- Comparison of coal-water slurry and blended coal combustion results.

## **INTRODUCTION**

During this period, analysis were performed on the gaseous emissions, ash analysis, particle size distribution of plant coal, ash x-ray floorescence analysis of

coal water fuel and feed stocks. Certain results of the analysis are included in the technical papers for presentations at Fourth Annual Historically Black Colleges and Universities/Private Sector-Energy Research and Development Technology Transfer Symposium, Greensboro, North Carolina, April 2-3, 1996.

## PROJECT STATUS

The study and analysis of combustion experimental data are in progress.

**Houshang Masudi (Principal Investigator) and Surender Samudrala (Graduate Research Assistant)**

Completed a paper entitled "Combustion Characterization of Coal-Water Slurry Fuel" for presentation at the Fourth Annual Historically Black Colleges and Universities/Private Sector-Energy Research and Development Technology Transfer Symposium, Greensboro, North Carolina, April 2-3, 1996.

(See Appendix A) - *Conference papers cycled separately* HH 3/4/98

**Surender Samudrala, (Graduate Research Assistant)**

Continued to analyze the combustion data for inclusion in his master thesis.

**Elna L. Reid, (Undergraduate Research Assistant)**

has been reviewing and summarizing a number of technical papers on coal-water slurry fuel. Her summarized work is shown in appendix B.

## CONCLUSIONS

1. Plant coal particles were analyzed for particle size distribution.
2. Ash particles were analyzed for chemical constituents.
4. Ash deposits and ash foulings were analyzed for elemental oxides.
3. Emissions of NO<sub>x</sub>, SO<sub>2</sub>, CO and CO<sub>2</sub> were analyzed for concentrations in gas flow.

## APPENDIX A

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## APPENDIX B

## Literature Review on an Advanced CWS-Fired Commercial- Scale Combustor System

Presently, an advanced CWS-fired combustor system for commercial-scale boilers and water heaters is being developed. Based on the IRIS (Inertial Reactor with Internal Separation) combustor, it has demonstrated 99 percent carbon conversion and NO<sub>x</sub> emissions less than .3 LB/10<sup>6</sup> Btu under staged operations in pilot-scale tests.

Achieving high conversion efficiencies and a residence time of the CWS particles, significant developments have been produced.

Concerning residence times of CWS particles being increased enables nearly complete carbon conversion for a wide range of particle droplet sizes. Within the facility a fine type boiler heat recovery unit, a slurry storage and handling system, an SO control system, and a particulate control system, and a control package are included with combustor.

Providing one third of the total energy consumed in the U.S. coal is the most plentiful energy resource. The program previously mentioned will demonstrate the technical and economic viability of a coal-fired combustion system. As a leading fuel coal-water slurry fuel has been selected for this effort of developing. CWS eliminates the need to use dry pulverized coal, which has handling, metering, and dusting problems, including explosive potential.

The CWS-fired commercial-scale space heating system being tested in three developmental and demonstrative stages. The first stage entails activities focused on component development and system integration. The second stage involves proof-of-concept testing. The final stage focuses on the system in an actual installation demonstration. The total system involved for testing includes combustor, CWS fuel, delivery system, boiler, pollution control, system controls, and a slurry preparation facility.

To provide a preliminary evaluation of components and system performance certain steps have been conducted. Identify key operating variables and their ranges, and establishing appropriate operating conditions for subsequent proof-of-concept testing are a few. The complete CWS-fired space heating system will be integrated into the facility existing heating system.

## Literature Review on the Preparation and Utilization of Slurry Fuel with Flotation Tailing

The flotation process is used with most coal preparation plants treating metallurgical coal. For full utilization of combustibles, the common practice of this operational process gives relatively low ash concentrate while leaving a medium ash tailing as an inferior fuel. Entailed in the inferiority are difficulties including handling, inefficiency, and pollutant. One possible option in solving these difficulties is the conversion of dewatered flotation tailing into slurry fuel.

To determine the flotation tailing ash content is observed which is high; and the heating value which is rather low for fuel. One attribute of tailing is particle size distribution that is of prime importance for a high-loaded coal slurry. No particles are larger than 300 microns. This requirement allows slurry fuel to avoid blockage of the atomizer nozzle. Size distribution of a particulate system affects its packing efficiency, or the volumetric concentration.

Slurry fuel preparation includes selection of additives, cost-effectiveness of additive formulation, and slurry fuel preparation process. Within the selection additives there are major functions. One being that no one dispersant alone is effective for promptly preparing a satisfactory slurry with such flotation tailing. Another function is slurry with acceptable rheology can be prepared. One other factor of selection of additives is that slurries with different additive formulation that have strong thixotropic character and had a relative high yield stress.

Under the process of slurry fuel preparation the flotation tailing comes out as filtering cake with a moisture content being lower than the water content of the final slurry fuel. Such slurry fuel will be combusted in boiler for hot water or stress raising. Special considerations include atomization, large turndown ratio, pre-combustors, and fly-ash collection and its disposal.

## Literature Review on Combustion Rates of Coal-Water Slurry Droplets

Experimental findings indicate combustion of coal-water fuels (CWF) takes place upon evaporation of the water and the heat-up of remaining solid agglomerate. Two distinct phases of this are 1. burning of the volatiles in an envelope flame, and 2. burning of the char heterogeneously. From the top of the furnace used for this testing pyrometric observations on the behavior of burning CWF particles were monitored from ignition extinction.

CWF can only be used as a substitute for oil in oil-fired furnaces with a small, loss in energy. CWF can provide coal-rich countries with an energy alternative. CWF is fundamental due to the ease of transportation and safety in pipelines with centralized crashing units. Determined problems are ignition and flame stability because of the large water content present.

Studies varied from single drop combustion in bench-scale equipment to large scale spray-flames in pilot plant furnaces, fuels of coal-oil mixtures (COM) tar-coal mixtures, coal-alcohol mixtures, etc. that have been investigated.

Obtaining combustion rates at conditions pertinent to those encountered in actual boilers allow sensitivity of the combustion behavior on particle size, and particle structural parameters, as well as combustion environments.

Four stages identified with the experimentation of single CWF drops are: 1. evaporation of water, 2. heat-up and pyrolysis of coal particle agglomerates, 3. evolution and gas-phase combustion of volatiles, and 4. heterogeneous combustion of the remaining char. To understand the different stages of CWF combustion isolated CWF drops were monitored in a non-intrusive manner throughout their lifetimes in high temperature environments. To clarify uncertainties on the elevated temperature combustion characteristics, obtaining accurate surface or flame temperatures. Such information facilities calculation of radioactive plumes and residence time in furnaces.

In this investigation coal used was bituminous, and the techniques used produce single droplets of coal-water slurries. Primary instrument was an injector. The injector was designed to perform a dual function: 1. enable injection of particles or drops at various heights in the furnace radiation cavity, and 2. enable pyrometric observations of burning particles from the top of furnace. Along with the injector as an instrument for experiments there are three other means for testing. The first is light collection optics which monitors the complete burnout history of the solid particle, from ignition to extinction. Second is the optical pyrometer, this provides high transmission efficiency dichroic beam splitters to separate the radiation spectrum to the three detectors needed. Last, data acquisition records the signals generated by the photo detectors to a microcomputer and a converter with a screw terminal board. Most studies were conducted with pre-dried CWF agglomerates to facilitate precise measurement of the initial particle size.

## Literature Review on Combustion Tests of Coal-Water Mixture for a Water-Tube Package Boiler

Combustion tests of coal-water mixture (CWM) fuel were performed in a water-tube package boiler. This particular burner was modified to burn CWM with a mixture of 70 percent coal and 30 percent water, this system was originally for oil firing. The efficiency ranges between 95-98.5 percent.

Many problems have been encountered using coal as fuel for industrial boilers. For instance, conditions of location of plants, and regulations on environmental protection. As far as conventional coal combustion methods there have been discrepancies with traveling-grate stoke firing method, pulverized coal firing method, and fluidized bed combustion method.

Points that must be checked for using CWM as fuel in industrialization are flame stability, combustion efficiency, low emissions of nitrogen oxides, derating of existing boiler originally designed for oil firing in association with switching of fuel to CWM, capability for loads, start-up and shut-down, durability of equipment, and stability of CWM.

The boiler used in the tests was a water-tube package boiler originally designed for oil firing with steam production capacity of 6 tons/hr and pressure of 16 kg/cm<sup>2</sup>. Other types of boilers include fire-tube boilers, fuel oil-designed industrial boiler, 32 megawatt pulverized coal boiler, and 600 megawatt utility boiler.

Larger furnaces used in testing emits more NO<sub>x</sub> and in order to reduce the emissions of NO<sub>x</sub> it is necessary to adjust the staging air. The loss of combustion happens due to a rise in the flame temperature, depending on the load. The loss of combustion from the rise in temperature shortened resident time in the furnace. Considering the load, adoption of an actual control system provides good capability of CWM.

Reliability of equipment , the boiler, CWM feed pump and atomizer; and the stability of CWM, using transportation tests, tank storage test, and resident in pipe, all allow good assets for results needed.

## SUMMARY

Over viewing various topics concerning coal as an alternative energy source, provided me with a valuable knowledge and understanding of the importance for an energy basis. Coal is the most plentiful resource being discussed and abundantly tested. There are many types of coal used depending on the testing done. Two major from were soft coal and superclean coal-water slurry. The different types allow for different results of effectiveness. Coal-water slurry eliminates the need to use dry pulverized coal, which has handling, metering, and dusting problems, including explosive potential.

Pertinent aspects that were discussed were combustion efficiency of equipment, disposal, storage ad handling, and to reduce emissions of  $\text{NO}_x$ , which is the combination of  $\text{NO}$  and  $\text{NO}_2$ .  $\text{NO}_x$  is the most difficult gas to minimize as a pollutant. The problems of air pollution provide a need of low emission combustion.

The low points of using coal as fuel for industrial boilers include conditions of location of plants and regulations on environmental protection. Different boilers are used for testing is a water-tube package boiler. Another type of boiler presented was a fire-tube boiler. These particular boilers are the major portion of small oil and gas fired boilers. The end result to using fire-tube boilers are to improve carbon burnout without major modifications to the boiler.

Other equipment includes furnaces. One special type mentioned was a cyclone furnace that provides up to 70% ash retention, and natural gas reburning will be used to keep  $\text{NO}_x$  emissions at a low level. This particular furnace will be retrofitted to industrial boilers to offset gas or oil premium fuel. To provide low ash concentrate is a process called flotation. It is used with most coal preparation plants that treat metallurgical coal for full utilization of combustibles. With low ash concentrate there is a medium ash tailing as an inferior fuel. Slurry fuel preparation includes the selection of additives, cost effectiveness of additive formulation and slurry fuel preparation process. The packed column flotation process is used for recovering coal from coal preparation plant waste streams. Before recovery preparation has been completed, coal preparation plants generate large amounts of waste that are dumped in large tailing ponds. As mentioned previously dumping is a significant problem. The solution for an alternative energy source has been determined, the major difficulty is solving this dilemma.

## ACKNOWLEDGMENTS

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