PROJECT

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U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Advanced Research

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MONITORING POWER PLANT EFFICIENCY USING THE MICROWAVE-EXCITED PHOTOACOUSTIC EFFECT TO MEASURE UNBURNED CARBON

Objective

The objective of this project is to explore the use of the microwave-excited photoacoustic (MEPA) effect for quantitative analysis of unburned carbon in fly ash, an extremely important parameter to the electric utility industry. Specific objectives include:

- Determine factors that influence accuracy and precision of the MEPA effect;
- Evaluate the microwave spectra of fly ash and other divided solids of importance to the power industry; and
- Determine the feasibility of an on-line carbon-in-ash monitor based on the MEPA effect.

Benefits

High carbon levels in coal ash indicate poor combustion efficiency, resulting in additional fuel requirements and higher emissions of pollutants, such as acid-rain forming sulfur dioxide and nitric oxides (NO_x). While a variety of instruments exist for monitoring gaseous emissions, integrated power plant managements is currently missing automated unburned carbon monitoring. The traditional method for measuring carbon in ash, the loss-on-ignition (LOI) test, is a tedious manual procedure requiring up to 48 hours to perform. An accurate carbon-in-ash monitor would play major roles in solving three problems facing electric utilities:

- Improving heat rates in aging boiler facilities;
- Optimizing performance of low-NO_x burners retrofitted into coal-fired boilers; and
- Reducing ash disposal costs.

Fast, accurate, and economical determination of carbon in ash is a key element in the solution of all these problems.

Scope

Three MEPA instruments have been constructed for this project. The first instrument is a single frequency, off-line instrument previously built at Iowa State University as part of proof-of-concept evaluations. The second instrument constructed as part of this project is a microwave spectrometer in the range of 500 MHz to 10 GHz that is used to evaluate the microwave spectra of fly ash. The final instrument built is based on the results of work with the previous two instruments and is designed to operate continuously and on-line.

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PROJECT COST

$509,473

PROJECT DURATION

10/01/2001 -09/30/2004

WEBSITES

www.netl.doe.gov/coal

Accomplishments

- The single frequency, off-line instrument allowed the determination of sample characteristics that are influential and those that are negligible. It was determined that how the sample was prepared, such as how compressed the sample was or how much of an air gap existed between the sample and the microphone, is critical. Unexpected non-linearities also arose when testing high carbon-content ash, which may have been caused by metal oxides.

- The microwave spectrometer was designed to operate in the range of 500 MHz to 10 GHz, which provides for added flexibility and robustness beyond that of the single frequency instrument. The microwave generation equipment was improved to stabilize the signal. To explore the influence metal oxides have on the photoacoustic effect, efforts were spent generating either a magnetic field or electric field source for the photoacoustic effect with the intent of discriminating between magnetic metal oxides and non-magnetic carbon.

- The on-line carbon-in-ash monitor has been constructed and has been tested for proper flow characteristics of the fly ash. The supporting electrical instrumentation and instrumentation parameters for both sensor-types are currently being evaluated and refined. Two different types of sensors are currently being investigated to quantify the MEPA effect of unburned carbon in the fly ash.

- The first sensor type is a MEMS-based accelerometer that is mounted on one side of an aluminum diaphragm, and on the other side of the diaphragm is the flowing column of fly ash. Microwaves induce a thermo-elastic effect in the fly ash, vibrating the diaphragm at the same frequency at which the microwaves are modulated. These vibrations are quantified by the accelerometer and are proportional to the unburned carbon-content in the fly ash.

- The second sensor type is a microphone directly exposed to the flowing column of fly ash, which is capable of detecting the expansion of the fly ash as it is heated by the microwaves.

- The supporting electrical instrumentation and instrumentation parameters for both sensor-types are currently being evaluated and refined.

Laboratory-scale of the on-line carbon-in ash monitor.