

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

Quarterly Technical Progress Report

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ABSTRACT

Three test instruments are being evaluated to determine the feasibility of using photo-acoustic technology for measuring unburned carbon in fly ash. The first test instrument is a single microwave frequency system previously constructed to measure photo-acoustic signals in an off-line configuration. This system was assembled and used to test parameters thought important to photo-acoustic signal output. A standard modulation frequency was chosen based upon signal to noise data gained from experimentation. Experiments were conducted during the seventh quarter to locate and eliminate microwave leakage from the off-line fly ash monitor. A preliminary cold-flow on-line fly ash monitor has been designed to evaluate the flow characteristics of the fly ash. Upon successful demonstration of repeatable, regular flow of the fly ash, design and construction of the hot-flow on-line fly ash monitor will commence.

Keywords: fly ash, carbon monitor, unburned carbon, boiler instrumentation

TABLE OF CONTENTS

DISCLAIMER	i
ABSTRACT	ii
INTRODUCTION	1
EXPERIMENTAL	1
The Single Microwave Frequency, Off-Line Instrument	1
The On-Line Monitor	4
RESULTS AND DISCUSSION	5

INTRODUCTION

The objective of this project is to explore the use of the microwave-excited photoacoustic (MEPA) effect for quantitative analysis of granular and powdered materials. The focal point of the research centers on the measurement of unburned carbon in fly ash, an important parameter in the electric utility industry used to determine plant efficiencies. The culmination of this project will be an on-line carbon-in-ash monitor for coal-fired power plants. However, evaluations will be made on other powdered solids, particularly coal.

The approach to this project includes work with three MEPA instruments. The first instrument is a single microwave frequency, off-line instrument built at Iowa State University as part of proof-of-concept evaluations. It is being used to evaluate precision and accuracy of the MEPA technique. The second instrument is being constructed as a microwave spectrometer based on MEPA. It will be used to evaluate a variety of industrial important powders, including fly ash and pulverized coal. The final instrument will be built based on the results of work with the previous two instruments and will be used as an on-line monitor of unburned carbon in fly ash.

EXPERIMENTAL

The Single Microwave Frequency, Off-Line Instrument

This quarter has been spent on troubleshooting the unexpected noise. The noise was caused by RF leakage from a RF microstrip component and a leaky coaxial cable. The noise problem was significant and detected after a variation was detected in several measurements that showed inconsistent and unrepeatable data. The root of the problem was not initially known and took some time to determine. RF leakage was identified as the root of the increasing noise level in measurement after a few weeks of efforts.

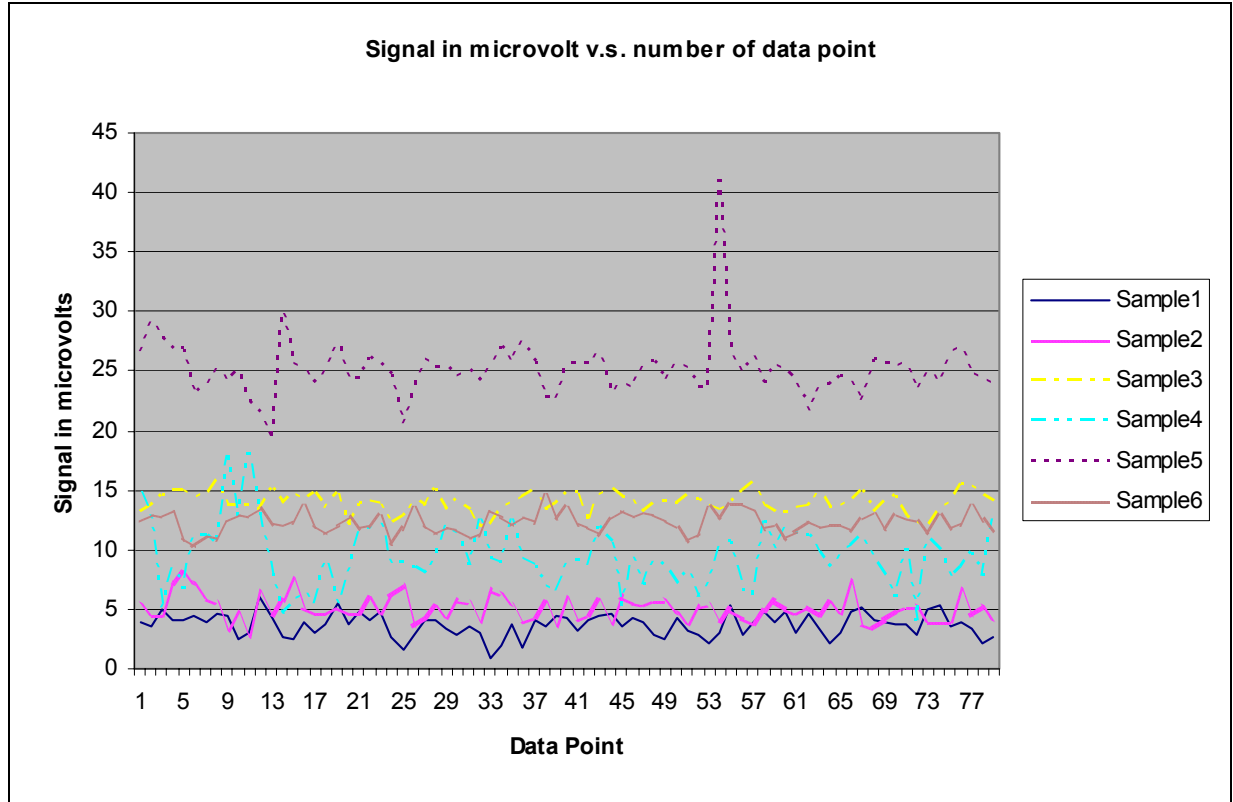


Figure 1: Variation of Data Set

As shown in Figure 1, the sample set showed significant variation from one point to another. This variation clearly demonstrates the occurrence of unexpected noise. Due to this variation of result, the average signal shown in Figure 2 no longer provides the linear plot that would be expected.

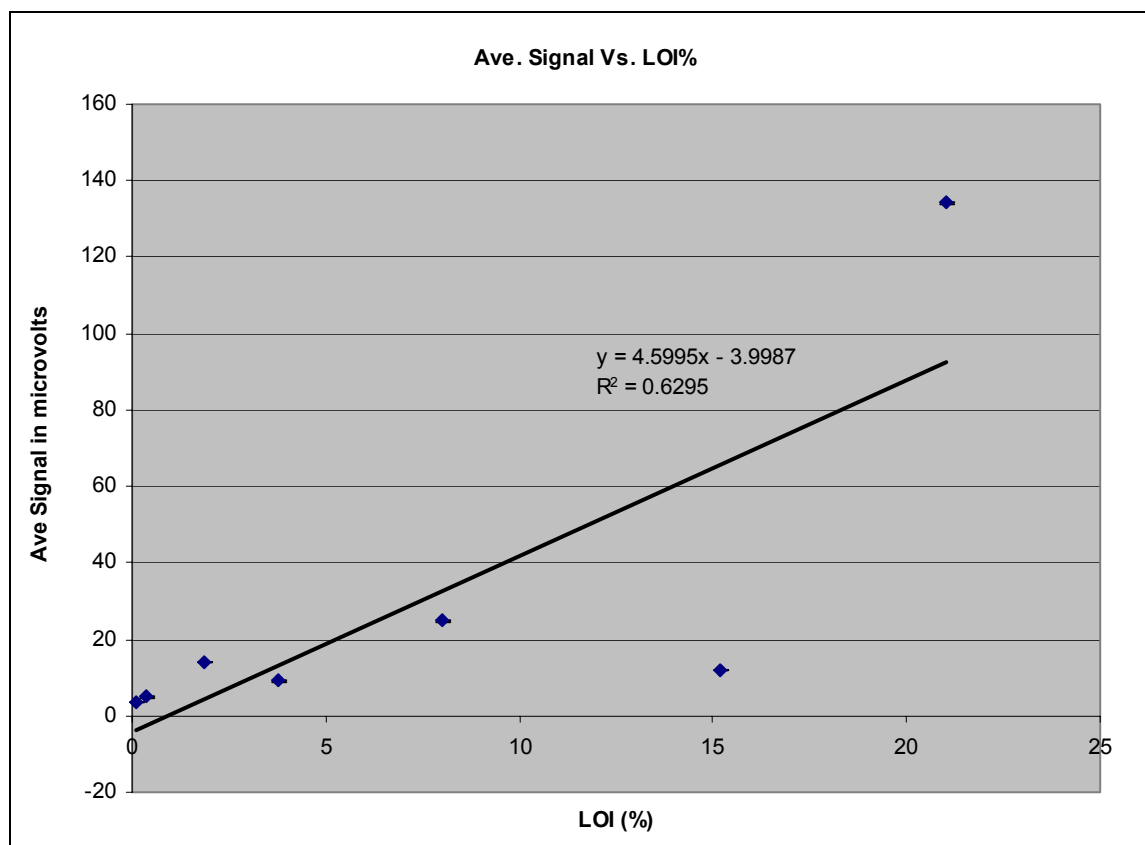


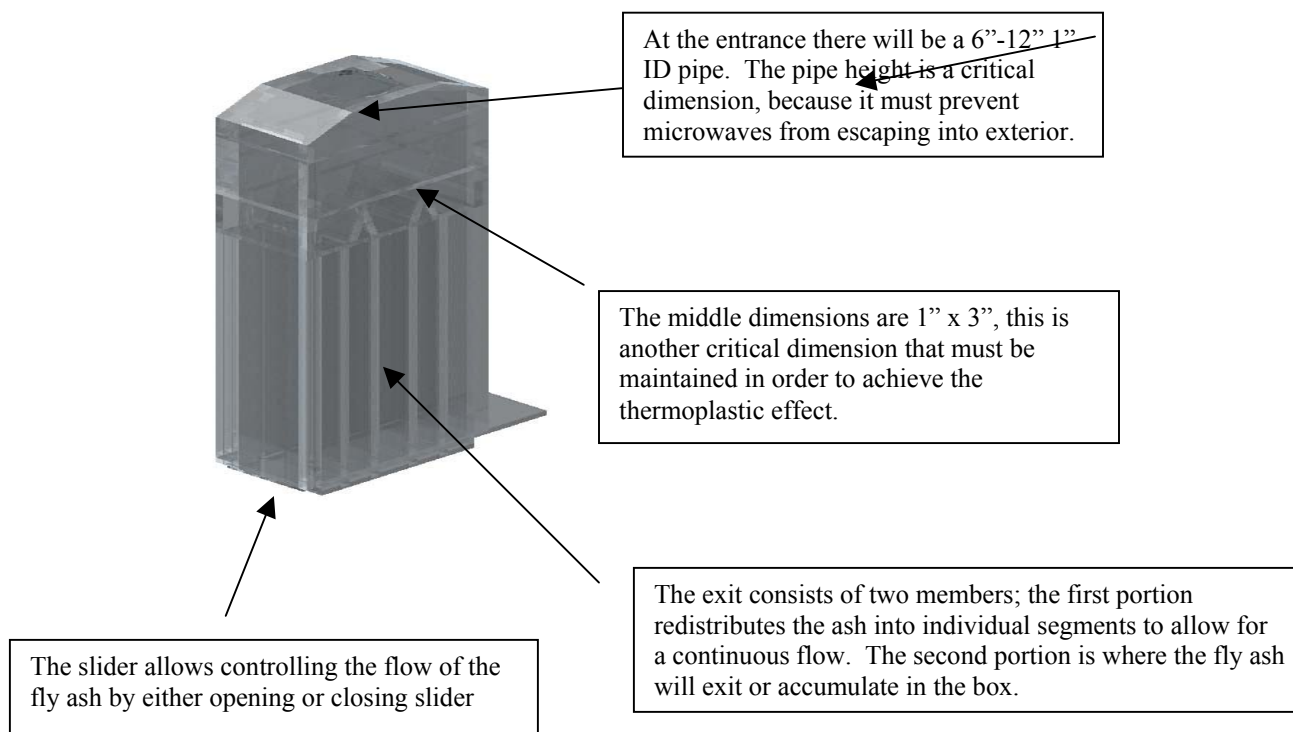
Figure 2: Linearity Plot of Average Signal

The troubleshooting effort to determine the root increased noise level was carried out using different methods. The most efficient method was using a spectrum analyzer with a receiving antenna to scan through the entire frequency range used by the photoacoustic system. Most of the tests were conducted with the spectrum analyzer set to the measurement frequency of the system (900MHz) and using zero span in the spectrum analyzer. With this configuration, RF leakage from the system is detected and demodulated. With this spectrum analyzer setting, both un-modulated and modulated levels are displayed. The amount of each signal (modulated versus un-modulated) indicates whether the signal is leaking from circuitry before carrier modulation or from circuitry passing modulated RF signals. After scanning through the photoacoustic system, two main source of RF leakage were identified. The main leakage came from a microstrip RF component, the pre-amplifier, in the power level control circuitry. This

component had not been shielded well and was causing unexpected RF leakage. This component was shielded and the RF leakage was reduced significantly. The leakage can not be totally eliminated but is now at what appears to be an acceptable level. Ferrite beads were placed on the outer conductors of the coaxial cable from the power amplifier to the test cell. The placement of the ferrite beads minimizes the effect of RF leakage from the leaks for the coaxial connector joints.

The On-Line Monitor

A preliminary cold-flow carbon fly ash monitor has been designed and is being fabricated out of clear polycarbonate to evaluate and characterize the flow of fly ash through the on-line monitor. This current cold-flow model has overall dimensions of 3.0" x 1.5" x 9.5", and consists of distinct three distinct regions: the inlet region, the test chamber, and the exit region. The inlet region is upstream of the test chamber, and is where the fly ash is introduced into the on-line monitor. The test chamber's dimensions are the most critical, which is where the source of the microwaves will be generated and where the accelerometer will be located to detect the thermo-elastic signal from the fly ash for the hot-flow model. The exit region consists of a vertical column with two baffles designed to prevent microwaves from escaping the test chamber, and a bottom gate to temporarily stop the flow of fly ash so that a prescribed quantity of fly ash can be collected and tested on a regular basis. As testing of this cold-flow model continues, it may require design modifications, as the goal is to allow the on-line monitor to completely fill with fly ash and then completely empty each time a sample is collected. Once a design is proven to meet these operational requirements, a hot-flow model will be constructed.



RESULTS AND DISCUSSION

This quarter focused on locating and eliminating microwave leaks in the off-line fly ash monitor and designing the preliminary cold-flow on-line fly ash monitor.