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# TECHNICAL PROGRESS REPORT

## (July 1, 1995 through September 30, 1995)

Prepared

for the Project

## CONTROL OF TRACE METAL EMISSIONS DURING COAL COMBUSTION

Thomas C. Ho
Department of Chemical Engineering
Lamar University
Beaumont, Texas

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Prepared by
**LAMAR UNIVERSITY**
Beaumont, Texas 77710
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Project Title: **CONTROL OF TRACE METAL EMISSIONS DURING COAL COMBUSTION**

DOE Grant Number: DE-FG22-94PC94221
Principal Investigator: Thomas C. Ho, Lamar University
DOE Project Officer: Mike Baird, PETC

## ABSTRACT

Emissions of toxic trace metals in the form of metal fumes or submicron particulates from a coal-fired combustion source have received greater environmental and regulatory concern over the past years. Current practice of controlling these emissions is to collect them at the cold-end of the process by air-pollution control devices (APCDs) such as electrostatic precipitators and baghouses. However, trace metal fumes may not always be effectively collected by these devices because the formed fumes are extremely small.

The proposed research is to explore the opportunities for improved control of toxic trace metal emissions, alternatively, at the hot-end of the coal combustion process, i.e., in the combustion chamber. The technology proposed is to prevent the metal fumes from forming during the process, which would effectively eliminate the metal emission problems. Specifically, the technology is to employ suitable sorbents to (1) reduce the amount of metal volatilization during combustion and (2) capture volatilized metal vapors. The objectives of the project are to demonstrate the technology and to characterize the metal capture process during coal combustion in a fluidized bed combustor.

The project was started on July 1, 1994 and this is the fifth quarterly technical progress report. Specifically, the following progress has been made during this performance period from July 1, 1995 through September 30, 1995:

1. **Response to Comments of Program Review** - Responses to the review comments from the DOE Fossil Energy Advanced Research Program Review were prepared and submitted.

2. **Combustion Experiments** - Combustion experiments involving both coal and wood pellets were conducted in the constructed quartz fluidized bed combustor. Typical sets of results are included in this progress report.

3. **New Atomic Absorption Spectrophotometer Ordered** - A new Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer equipped with a continuous flow hydride generator was ordered for the project.

4. **Conference Presentations** - A mini-paper, entitled "Capture of Toxic Metals by Various Sorbents during Fluidized Bed Coal Combustion," was prepared for the 1995 AIChE Annual Meeting to be held in Miami, November 13-17, 1995.

## EXECUTIVE SUMMARY

Toxic (or potentially toxic) trace metallic elements such as barium, beryllium, boron, cadmium, chromium, lead, mercury, nickel, selenium, strontium, vanadium, zinc and zirconium are usually contained in coal in various forms. These metals will either stay in the ash or be vaporized during high temperature combustion. Portions of the vaporized metals may eventually be emitted from a combustion system. Most of the emitted metals will be in the form of metal fumes or particulates with diameters less than 1 micron and are potentially hazardous to the environment. The U.S. EPA has reported that metals account for almost all of the identified risks from waste incineration systems.

Concern over toxic trace metal emissions from coal-fired combustion sources is growing, especially as the result of the passage of the 1990 Clean Air Act Amendments (CAAA). To address the concern, the U.S. DOE has recently co-sponsored a workshop jointly with the Electric Power Research Institute (EPRI) and the Energy and Environmental Research Center (EERC) on Trace Elements Transformations in Coal-Fired Power Plants. The objective of the workshop was to evaluate the current level of understanding on metal behavior during coal combustion and to identify potential technologies for improved metal emission control.

Current practice of controlling trace metal emissions during coal combustion employs conventional air pollution control devices (APCDs), e.g., venturi scrubbers, electrostatic precipitators, baghouses etc., to collect fly ash and metal fumes. This type of control is essentially a cold-end control because metals are allowed to vaporize and condense before being controlled. The control may not always be effective on metal fumes due to their extremely fine sizes.

An alternative technology for metal emission control is to minimize the formation of metal fumes at the hot-end of the coal combustion process, i.e., in the combustion chamber. The technology proposed is to prevent the metal fumes from forming during the process, which would effectively eliminate the metal emission problems. Specifically, the technology is to employ suitable sorbents to (1) reduce the amount of metal volatilization during combustion and (2) capture volatilized metal vapors. The objectives of the project are to demonstrate the technology and to characterize the metal capture process during coal combustion in a fluidized bed combustor.

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3. **New Atomic Absorption Spectrophotometer Ordered** - A new Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer equipped with a continuous flow hydride generator was ordered for the project.

4. **Conference Presentations** - A mini-paper, entitled "Capture of Toxic Metals by Various Sorbents during Fluidized Bed Coal Combustion," was prepared for the 1995 AIChE Annual Meeting to be held in Miami, November 13-17, 1995.

## DETAILED PROGRESS REPORT

### 1. Response to Comments of Program Review

A DOE Fossil Energy Advanced Research Program Review was conducted in Nashville, Tennessee on June 13, 1995. This project was reviewed under Topic 19 - Combustion Ash and Byproducts. Confidential review comments resulted from the review were received by the Principal Investigator on September 5, 1995 and our responses to the comments were prepared and submitted to the UCR Program Coordinator on September 15, 1995. We are especially pleased with the panel's comments that "this is a good project deserving of continuing support" and that "alternations in the approach described by the project are important and can be accomplished by the Principal Investigator."

One of the constructive suggestions from the panel members is to start the project by burning simulated combustible fuel with controlled metal concentration (e.g., wood pellets spiked with controlled metal concentration) instead of burning coal. The reason behind this is to avoid the problem of non-uniform metal concentration in coal. We consider this an excellent suggestion and have been following their advice to design our experiments.

### 2. Combustion Experiments

Several combustion experiments involving both coal and wood pellets were conducted in the constructed quartz fluidized bed combustor during this performance period. Typical experimental results are summarized in Table 1 in ATTACHMENT 1. In general, these results indicate that different sorbents have various potential of capturing different metals. Zeolite has been observed to be effective in capturing the three metals, i.e., lead, cadmium and chromium. Note that additional combustion experiments are currently being carried out to provide statistically representative data and more discussions regarding the metal capture process will be made in the next progress report.

It should be pointed out that our current atomic absorption spectrophotometer (Perkin Elmer Model 2100) was ineffective in measuring the trace concentration of arsenic and selenium and no results on these two metals are included in this report. However, a new Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer equipped with a continuous hydride generator especially designed for arsenic and selenium was ordered and the results on these two metals will be reported in the next progress report.

### 3. New Atomic Absorption Spectrophotometer Ordered

A new Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer (AAS) equipped with a continuous flow hydride generator was ordered for the project. The equipped hydride generator is expected to provide much needed detectability in the measuring of trace metal concentrations, especially for arsenic and selenium. A description of the Buck Scientific Continuous Flow Hydride/Cold Vapor System for parts-per-trillion level detectability is included in ATTACHMENT 2.

### 4. Conference Presentations

A mini-paper, entitled "Capture of Toxic Metals by Various Sorbents during Fluidized Bed Coal Combustion," was prepared for the 1995 AIChE Annual Meeting to be held in Miami, November 13-17, 1995. The paper is included in this report in ATTACHMENT 3.

## FUTURE WORK PLANNED

The work planned for the next quarter will be to continue metal capture experiments in the quartz fluidized bed combustor. Both wood pellets and coal will be involved in the experiments. The metal concentration in the wood pellets will be controlled to the same level as in typical coal. Metal capture efficiency will be characterized under various combustion conditions. Arsenic and selenium concentrations will be measured using the new Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer.

# ATTACHMENT

1. Table 1. Percent Metal Capture by Various Sorbent during Coal and Wood Combustion.

2. Description of Buck Scientific Continuous Flow Hydride/Cold Vapor System.

3. Mini-paper, entitled "Capture of Toxic Metals by Various Sorbents during Fluidized Bed Coal Combustion," for AIChE Miami Annual Meeting. Removed for separate recycling at

## ATTACHMENT 1

Table 1. Percent Metal Capture by Sorbents during Coal and Wood Combustion

| Combustion | Sorbent | Lead | Chromium | Cadmium |
|---|---|---|---|---|
| Wood[1] | Zeolite | 69 | 54 | 43 |
| | Bauxite | 59 | 0 | 19 |
| | Lime | 67 | 79 | 0 |
| Coal[2] | Zeolite | 76 | 58 | 51 |
| | Bauxite | 62 | 0 | 0 |
| | Lime | 3 | 25 | 0 |

Note:

1. Original Metal Concentration: Pb - 30 ppm; Cr - 20 ppm; Cd - 5 ppm
   Wood Amount: 30 g
   Sorbent Amount: 12 g
   Sorbent Size: Mesh #30-#40
   Combustor Temperature: 900°C
   Air Flow Rate : 13.9 - 15.2 cm/sec (3 $U_{mf}$)
   Duration: 6 hrs

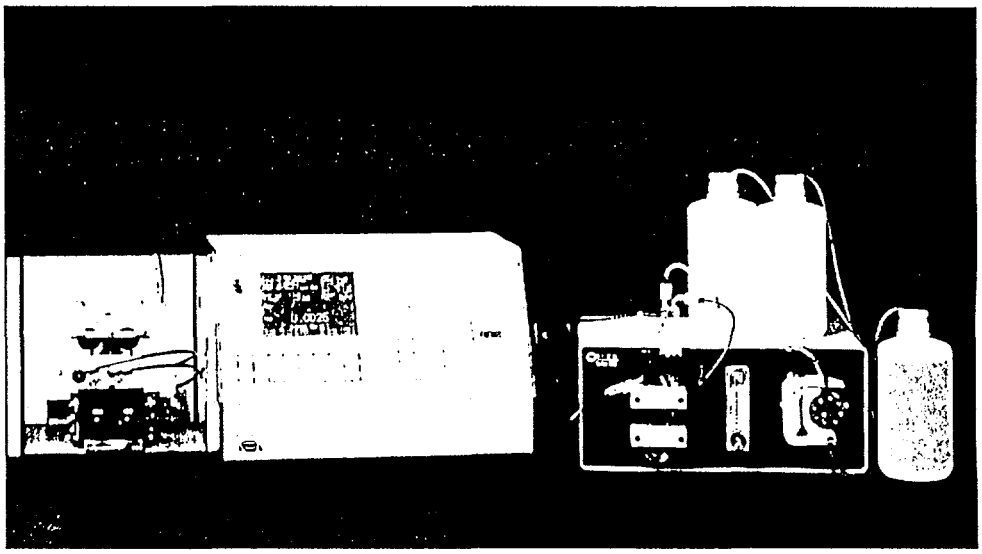
2. Original Metal Concentration: Pb - 27 ppm; Cr - 14 ppm; Cd - 0.3 ppm
   Coal Amount: 30 g
   Sorbent Amount: 12 g
   Sorbent Size: Mesh #30-#40
   Combustor Temperature: 900°C
   Air Flow Rate : 13.9 - 15.2 cm/sec (3 $U_{mf}$)
   Duration: 6 hrs

# Buck Scientific
# Continuous Flow Hydride/Cold Vapor System

*For parts-per-trillion level detectability*

## Overview

The Model-420 is an easily adaptable accessory for Flame AA Spectrophotometers that allows PPT detectability for As, Se, Sb, Sn, Te, Bi and Ge using standard hydride generation procedures. Using inert polymer components and a reliable pumping system, users can quickly switch between flame and hydride.



## Features

- Allows superior detection limits for hydride metals compared to graphite furnace AAS, typically in the 100-500 parts-per-trillion range.
- Can install easily and rapidly to existing flame set-up and run within 2 minutes.
- Does not require hydrogen gas
- Continuous flow pump design allows for simple interfacing of intelligent auto-sampler for high-throughput, unattended operation.
- 4 order of magnitude dynamic range using the Buck Model 210VGP AA system for the highest accuracy over a wide range of sample concentrations.....minimizing dilutions and errors.
- Inert tubing gives rapid equilibration time allowing typical throughputs of 50 samples per hour with reproducibilities of better than 2% at the 500 ppt level.
- Optimized procedures for *all* the hydride elements eliminates development time and simplifies operations for the chemist or lab technician.
- Low format footprint requires minimal bench space and unit can be put on a cart or side table.

BUCK Scientific *Affordable Quality*

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