Program status: Completed

PROGRAM FACT SHEET

Trace Elements Emitted During Stationary Combustion

Goals

The goals were to characterize trace element emissions, investigate the use of ceramic filters for reducing mercury emissions, and develop a unified methodology for the measurement of trace elements and mercury species in combustion flue gas.

Team

Participants in The Energy Institute program included U.S. Departments of Energy and Defense, AMAX Research & Development Center, CQ, Inc., Clean Air Engineering, CeraMem Separations, Inc., Corning Incorporated, Ontario Hydro, and the University of North Dakota Energy and Environmental Research Center.

Program Discussion

Penn State's stationary combustion emissions program encompasses the formation and control of pollutants from all types of boilers, firing a variety of fuels, and using multiple control options. One major focus in this program was to perform detailed characterization of inorganic hazardous air pollutants (IHAPs) listed in the Title III Clean Air Act Amendments of 1990 from coal-fired boilers. IHAPs include the following elements: arsenic, beryllium, cadmium, cobalt, manganese, nickel, lead, antimony, selenium, and mercury. The program was conducted to assist DOE in identifying control strategies for mercury removal and to develop a stack testing sample train and methodology to simultaneously sample, from combustion flue gas, mercury species and IHAPs.

Stack Testers

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Background

Title III of the Clean Air Act Amendments of 1990 designates 188 HAPs, of which the inorganic HAPs are listed above. Of these IHAPs, mercury has been of primary concern given its significant negative health effects on humans and wildlife. The U.S. Environmental Protection Agency (EPA) initiated an information collection request (ICR) on January 1, 1999 for coal-fired electric utility steam generating units (> 25 MW_e) to document mercury levels in their fuels and emissions. In December 2000, EPA announced that it will require reductions of mercury emissions from coal-fired plants.This culminated with the passing of the Clean Air Mercury Rule on March 15, 2005 to permanently cap and reduce mercury emissions from coal-fired power plants.

Concurrent with the mandated removal of mercury, is the interest in reducing fine particulate emissions. For many years, there has been considerable interest in revising the national ambient air quality standards (NAAQS) with respect to fine particulate emissions (i.e., $PM_{2.5}$). This culminated in the promulgation of new NAAQS for $PM_{2.5}$ in September 1997. While the legislation was impending, the DOE initiated several projects, which are exploring the use of new, or modifying existing technologies to reduce fine particulate emissions from coal-fired boilers. DOE's objective was to identify control technologies should legislation mandate reduction in $PM_{2.5}$ emissions from coal-fired boilers. The objective of the Penn State project was to evaluate ceramic membrane filters for fine particulate control and their ability to reduce mercury emissions.

Penn State worked with DOE and industry to evaluate IHAP and fine particulate emissions from coal-fired boilers. The technical issues addressed in the program included: 1) ceramic filter collection performance and regeneration; 2) multielement composition and mercury speciation of the emissions; 3) the development of a hybrid of EPA Method 29 and modified Ontario Hydro Method (i.e., PSU Method); 4) comparison of particulate emissions between a ceramic filter chamber and a conventional fabric filter baghouse; 5) the effect of coal cleaning on emissions; 6) the effect of boiler operating conditions on emissions; and 7) the effect of fuel form (micronized coal and coal-water slurry fuels) on emissions.

Results

A brief summary of key aspects of the program are given below:

Development of a Unified Methodology

A sample train and methodology (referred to as the PSU Method) were developed to simultaneously sample from combustion flue gas mercury species and IHAPs. The PSU Method train consists of components of both the Ontario Hydro Method (for mercury speciation) and EPA Method 29 (for multielements) sampling trains (Fig. 1).

Duplicate simultaneous tests were performed at the inlet and outlet of a baghouse connected to a two million Btu/hr A-frame watertube boiler. Deeply-cleaned Taggart seam hvA bituminous coal from Virginia was burned during the tests. A statistical analysis (a two sample *t*-test with unpaired, *i.e.,* unequal, variances at a 95% confidence interval) demonstrated that the two sample sets generated for each element by the two methods at the baghouse inlet and outlet were from the same populations at a 95% confidence interval ($P > 0.05$). The PSU Method produced data for the multielements that were statistically indistinguishable from data produced by Method 29. Statistical analysis of the mercury species data showed that the sample sets generated by the PSU Method and the Ontario Hydro Method were equal and were derived from the same population.

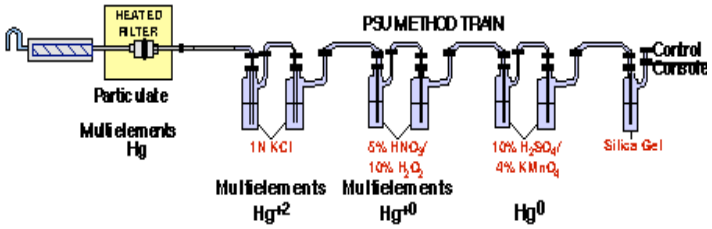
The study demonstrates that the PSU Method is capable of simultaneously sampling mercury species and all inorganic trace elements listed as HAPs. Data sets generated by the PSU Method are statistically indistinguishable from data produced by Method 29 for multielements and the Ontario Hydro Method for mercury species.

Mercury Reduction using Ceramic Membrane Filters

Tests were conducted, using EPA Method 29, to determine the emissions of trace elements from the ceramic membrane filters and fabric filters when firing micronized coal. Mercury emissions from the ceramic filter were 79% lower than from the baghouse (0.12 versus 0.56 lb mercury/ trillion Btu, respectively). The material balances on mercury through the system and across the filters were also very good. In addition, approximately 30% of the mercury that entered the baghouse was emitted to the atmosphere, whereas less than 10% of the mercury entering the ceramic filter was emitted. Since the ceramic filter captures more of the fine particulate, it is likely that the mercury is condensed on the fine particles.

The Effect of Fuel Form and Cleaning on Trace Element Emissions

The effect of coal cleaning and fuel form on toxic emissions were investigated using several coals provided by CQ Inc. and Cyprus-AMAX Research & Development Center. Cyprus-AMAX provided Penn State with a suite of coals (i.e., filter cakes) cleaned under the U.S. Department of Energy's Premium Fuel Program. The coals were from the Taggart seam (Virginia), Indiana VII seam (Indiana), and Hiawatha seam (Utah) which have been cleaned using advanced column flotation and oil agglomeration. CQ Inc. provided Penn State with coals from the Pittsburgh, Kittanning, and Freeport seams from Pennsylvania, which have been cleaned using a combination of heavy media cyclones, water spirals, and froth flotation. Specific results from this work can be found in papers listed in the Key Publications section.



PSU Sample Train Configuration
(Comparison to Method 29 and Ontario Hydro Sample Trains)

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Key Publications

Miller, B.G., S. Falcone Miller, S.V. Pisupati, C. Song, R.S. Wasco, R.T. Wincek, X. Xu, A.W. Scaroni, R. Hogg, S. Chander, M.T. Ityokumbul, M.S. Klima, P.T. Luckie, A. Rose, R.L. Gordon, J. Lazo, and A.M. Schaal, "The Development of Coal-Based Technologies for Department of Defense Facilities; Phase III Final Report, Prepared for the U.S. Department of Energy Federal Energy Technology Center, Pittsburgh, Pennsylvania, Phase III Final Report, January 30, 2004 665 pages; Phase II Final Report, July 31, 2000, 784 pages; Phase I Final Report, January 31, 1997, 590 pages; DE-FC22-92PC92162.

Miller, B. G., S. Falcone Miller, R. T. Wincek, and A. W. Scaroni, "A Demonstration of Fine Particulate and Mercury Removal in a Coal-Fired Industrial Boiler Using Ceramic Membrane Filters and Conventional Fabric Filters," *EPRI-DOE-EPA Combined Utility Air Pollutant Symposium "The Mega Symposium",* Atlanta, Georgia, August 16-20, 1999.

Falcone Miller, S., R. T. Wincek, B. G. Miller, and A. W. Scaroni, "The Effect of Fuel Form on Trace Element Emissions in an Industrial-Scale Coal Fired Boiler, *The Fifteenth International Pittsburgh Coal Conference*, Pittsburgh, Pennsylvania, September 14-18, 1998. (pdf)

Falcone Miller, S., R. T. Wincek, B. G. Miller, and A. W. Scaroni, "Trace Element Emissions when Firing Pulverized Coal in a Pilot-Scale Combustion Facility," *23rd International Technical Conference on Coal Utilization & Fuel Systems*, Coal & Slurry Technology Association, pp. 953-964, March 9-13, 1998. (pdf)