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Comparison of HAPs from Advanced and Conventional Power Systems: Tidd Versus Cardinal

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DISCLAIMER

6B.2 Comparison of HAPs From Advanced and Conventional Power Systems: Tidd Versus Cardinal

CONTRACT INFORMATION

Contract Number	DE-AC21-92MC28016
Contractor	Energy & Environmental Research Center University of North Dakota 15 North 23rd Street Grand Forks, ND 58203
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FY95–96 Program Schedule

	O	N	D	J	F	M	A	M	J	J	A	S
Task 1 Technical Review of Available Data	—	—	—	—	—	—	—	—	—			
Task 2 Presentation of Available Data			—	—	—	—	—	—	—	—	—	—
Task 3 Assessment of Control Options					—	—	—	—	—	—	—	—
Task 4 Reporting	—	—	—	—	—	—	—	—	—	—	—	—

OBJECTIVES

The goal of this project is to evaluate available hazardous air pollutant (HAP) emissions data from advanced power systems and compare those data with data from conventional systems. The specific objectives of this program are to 1) perform a technical review and assessment of the data accumulated on the fate of trace metals and other HAPs in advanced coal power systems and compare them to data on emissions from conventional pulverized coal power plants and 2) assess the effectiveness of conventional and innovative control technologies relative to potential regulation requirements.

BACKGROUND INFORMATION

The Clean Air Act Amendments (CAAA) of 1990 identified 189 substances as air toxics or HAPs. Under the CAAA, the U.S. Environmental Protection Agency (EPA) must regulate emissions of these HAP at their sources, including advanced power systems used for the production of electricity. The EPA will also gain more authority for regulating emissions of these air toxics under the CAAA. The EPA will define those sources that require regulation and limit their emissions according to regulatory directives.

This project is an addition to an existing U.S. Department of Energy (DOE) program entitled Trace Element Emissions (TEE), which is being conducted by the Energy & Environmental Research Center (EERC). The purpose of this additional work is to examine and evaluate the HAPs emissions data currently available from full-scale and demonstration units employing advanced power or hot-gas cleanup systems. The majority of the HAPs data are already available, and the results of recent sampling at advanced system sites need to be analyzed and condensed. Advanced systems employ a variety of sulfur capture methods and particulate filtration concepts that are expected to interact differently with trace elements and organic compounds. The effectiveness of conventional and innovative control technologies in advanced systems needs to be evaluated to determine the differences between the various desulfurization and filtration concepts. The data will be analyzed for trends associated with collection systems and operating conditions.

PROJECT DESCRIPTION

To accomplish the above-mentioned goal and objectives related to this work, a three-task approach has been adopted: Task 1 – Technical Review of Available Data, Task 2 – Presentation of Available Data, and Task 3 – Assessment of Control Options. Each of these tasks is discussed in more detail below.

Task 1 – Technical Review of Available Data

The purpose of this first task is to locate and technically review the existing data from advanced power systems. Data will be evaluated for their technical merit to determine if the sampling, sample recovery, measurements, and data interpretation methodologies are appropriate and consistent. The review process is divided into four areas: Acquisition of data reports, review of sampling appropriateness and adequacy, review of analytical appropriateness and adequacy, and review of data manipulation and statistical procedures.

The acquisition of data reports includes the search for and retrieval of reports and other forms of information relating to the emission of HAPs for both advanced and conventional power systems. Though the work is concentrated on advanced systems, conventional systems are also being reviewed for comparison purposes, since most regulations are expected to be based on conventional systems.

The review of both sampling and analytical procedures is done to ensure that comparisons between different information sources are appropriate. The review includes the evaluation of equipment testing, field and laboratory blanks, standards, and spikes, if performed. When information is lacking or is obviously erroneous, it is either qualified when reported or replaced with a better estimate. Similarly, the methods used for manipulating and reporting the data will be reviewed, and a single technique for data presentation will be chosen.

Task 2 – Presentation of Available Data

The second task is designed to place all of the pertinent data into an easily accessible format for additional manipulation and comparisons, perform the comparisons, and present the resultant information in an easy-to-use format. The presentation of information includes the manipulation and comparisons of data within a single system as well as for multiple systems. A relational database and/or spreadsheets are used for storage of the information and for processing of the data.

Task 3 – Assessment of Control Options

This task compares specific advanced power system and gas cleanup technologies for the ability to meet potential regulatory requirements for the emission of HAPs. Comparisons of these technologies are made based on the data reports and assumptions of how each would operate under similar conditions. Comparisons between advanced and conventional coal conversion systems are also made. The assessment is being accomplished in four areas: Review of proposed/potential EPA regulations, HAPs emission characteristics from advanced power systems, assessment of pollutants in solid residues, and review of control technologies and potential control technologies.

The current status of EPA regulations that may pertain to advanced power systems is being explored. EPA regulations regarding coal utilization, waste incineration, and other forms of fossil fuel use are being reviewed. Potential regulations are being anticipated based on regulations currently in place, CAAA literature, and other sources.

HAPs emissions as a function of control technology are being correlated for all of the different data sets reviewed. In addition, results from the advanced power systems are being compared with existing data from conventional power systems to determine the differences between their potential impacts on the environment.

Although HAPs in solid residues have not drawn as much attention as air emissions, they are, nonetheless, potentially detrimental to the environment. The potential environmental risks of solid residues and their impact on the environment are being assessed based on existing data in the reports.

After the control technologies from these reports have been evaluated for their effectiveness on HAPs emissions, they will be compared with other control technologies for which data are available but which are not part of the advanced power systems development effort at this time. Based on the characteristics of the HAPs emitted, other control technologies will be researched for their potential benefits to advanced power systems.

Deliverables

The primary deliverable from this work will be a detailed report presenting all of the information collected under the scope of the work, including 1) a review of the sampling procedures currently used in advanced power systems, 2) a review of the analytical techniques used in characterizing samples from advanced power systems, 3) an assessment of the impact of advanced power systems on the environment, 4) an assessment of the impact of high-temperature gas cleanup systems on HAPs emissions, and 5) recommendations for future work under the DOE program to mitigate HAPs. This topical report will be entitled "Assessment of Hazardous Air Pollutants for Advanced Power Systems."

RESULTS

The work performed on this project to date has centered around the evaluation of data from the Tidd pressurized fluid-bed combustor (PFBC) and advanced particulate filter (APF), the General Electric (GE) hot-gas cleanup unit (HGCU), and information from conventional systems. A brief description of these systems, including their location, furnace type, fuel type, control technologies type and temperature, and any SO_2 and NO_x control systems, is shown in Table 1. Three sets of results are summarized below: Comparison of Tidd PFBC and Cardinal pulverized coal (pc)-fired combustor, comparison of Tidd APF and electrostatic precipitator (ESP) with Cardinal ESP, and summary of conventional and advanced power system collection efficiencies and emission factors.

Comparison of Tidd PFBC and Cardinal pc-Fired Combustor

Trace element partitioning from the Tidd PFBC system has been compared to the Cardinal pc-fired plant, which is located adjacent to it. The ratio of the mass of a given trace element in the exiting flue gas to that leaving the system in the bottom ash for both systems is shown in Figure 1. The flue gas ash is measured at the inlet of the APF for the Tidd Station and at the inlet to the ESP for the Cardinal Station. These two plants burn the same Pittsburgh No. 8 coal, although there is a significant length of time between the two sampling events over which time the coal samples may vary, making comparisons fairly easy. The partitioning that occurs within the power system boiler directly affects the amount of any metal reaching the gas cleanup site and potentially impacts the amount emitted from the total system. For all trace elements except mercury, the PFBC system at Tidd released fewer trace elements into the flue gas stream (entering the APF) than the Cardinal Station (entering the ESP). For mercury, both systems released essentially 100% into the flue gas, and none remained with the bottom ash of the systems. Figure 2 shows the amount of trace elements exiting in the Tidd PFBC flue gas that are in the vapor state. Cl, F, and Hg are primarily in the vapor state, and Cu, Mo, Ni, and Se contain greater than 10% of their mass in the vapor state. The remaining elements were primarily present as particulate.

Table 1. Operational Information and System Design for Conventional and Advanced Systems

Plant	Plant Yates Unit No. 1 (1)	Cardinal Plant Unit No. 1 (2)	Boswell Energy Center Unit No. 2 (3)	Baldwin Power Station Unit No. 2 (4)	Coal Creek Station Unit No. 1 (5)	Niles Station Unit No. 2 (6)	Niles/ SNOX (7)	Springerville Generating Station Unit No. 2 (8)	Bailly Station Units No. 7 and 8 (9)	Plant Tidd ESP Unit (10)	Plant Tidd APF Unit (10)	GE HGCU (11)
Location	Newnan, GA	Brilliant, OH	Cohasset, MN	Baldwin, IL	Underwood, ND	Niles, OH	Niles, OH	Springerville, AZ	Chesterton, IN	Brilliant, OH	Brilliant, OH	Schenectady, NY
Furnace Type	Tangentially fired, dry bottom	Opposed wall-fired, dry bottom	Front-fired, dry bottom	Cyclone-fired	Tangentially fired, divided, dry bottom	Cyclone-fired	Cyclone-fired	Tangentially fired, dry bottom	Cyclone-fired	PFBC	Pressurized fluidized-bed combustor	Pressurized fixed-bed gasifier
Fuel	Illinois No. 5, Illinois No. 6 bituminous blend	Pittsburgh No. 8 bituminous	Powder River Basin subbituminous	Illinois bituminous	North Dakota lignite	Pennsylvania/ Ohio bituminous blend	Pennsylvania/ Ohio bituminous blend	New Mexico subbituminous	Illinois/ Indiana bituminous	Pittsburgh No. 8 bituminous	Pittsburgh No. 8 bituminous	
Particulate Control	ESP	ESP	Baghouse	ESP	ESP	ESP	Baghouse	Baghouse	ESP	ESP	APF	Primary and secondary cyclones
Particulate Control Unit Operating Temperature	280°F	300°F	350°F	335°F	320°F	300°F	390°F	180°F	310°F	400°F	1350°F	1000°F
SO_2 Control	Jet bubbling reactor (JBR)	None	None	None	Wet flue gas desulfurization	None	Wet gas sulfuric acid (WSA)-SNOX	Spray dryer absorbers	Advanced flue gas desulfurization (AFGD)	None	None	HGCU
NO_x Control	Tangentially fired	None	None	None	Tangentially fired/overfire air	None	WSA-SNOX	Tangentially fired/overfire air	None	None	None	None

1 Radian Corporation. "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP While Demonstrating the ICCT CT-121 FGD Project," Final Report for DOE Contract No. DE-AC22-93PC93252; June 1994.
2 Energy and Environmental Research Corporation. "Assessment of Toxic Emissions from a Coal Fired Power Plant Utilizing an ESP," Final Report for DOE Contract No. DE-AC22-93PC93252; December 1994.
3 Weston. "Toxics Assessment Report, Minnesota Power Company, Boswell Energy Center - Unit 2", Final Report for DOE Contract No. DE-AC22-93PC93255; July 1994.
4 Weston. "Toxic Assessment Report, Illinois Power Company, Baldwin Power Station - Unit 2," Final Report for DOE Contract No. DE-AC22-93PC93255; July 1994.
5 Batelle. "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP/Wet FGD System," Final Report for DOE Contract No. DE-AC22-93PC93251; July 1994.
6 Battelle. "A Study of Toxic Emissions from a Coal-Fired Power Plant - Niles Station Boiler No. 2," Final Report for DOE Contract No. DE-AC22-93PC93251; June 1994.
7 Battelle. "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing the SNOX Innovative Clean Coal Technology Demonstration" Final Report for DOE Contract No. DE-AC22-93PC93251; July 1994.
8 Southern Research Institute. "Springerville Generating Station Unit No. 2," Final Report for DOE Contract No. DE-AC22-93PC93254; June 1994.
9 Southern Research Institute. "Bailly Station Units 7 and 8 and AFGD ICCT Project," Final Report for DOE Contract No. DE-AC22-93PC93254; August 1994.
10 Radian Co. "A Study of Hazardous Air Pollutants at the Tidd PFBC Demonstration Plant," Draft Report for DOE Contract No. 94-633-021-02; September 1994.
11 Radian Co. "Trace Element Determinations During Integrated Operation of a Pressurized Fixed Bed Gasifier, Hot Gas Desulfurization System, and Gas Turbine Simulator," Final Report for DOE Contract No. 94-643-011-01; July 1994.

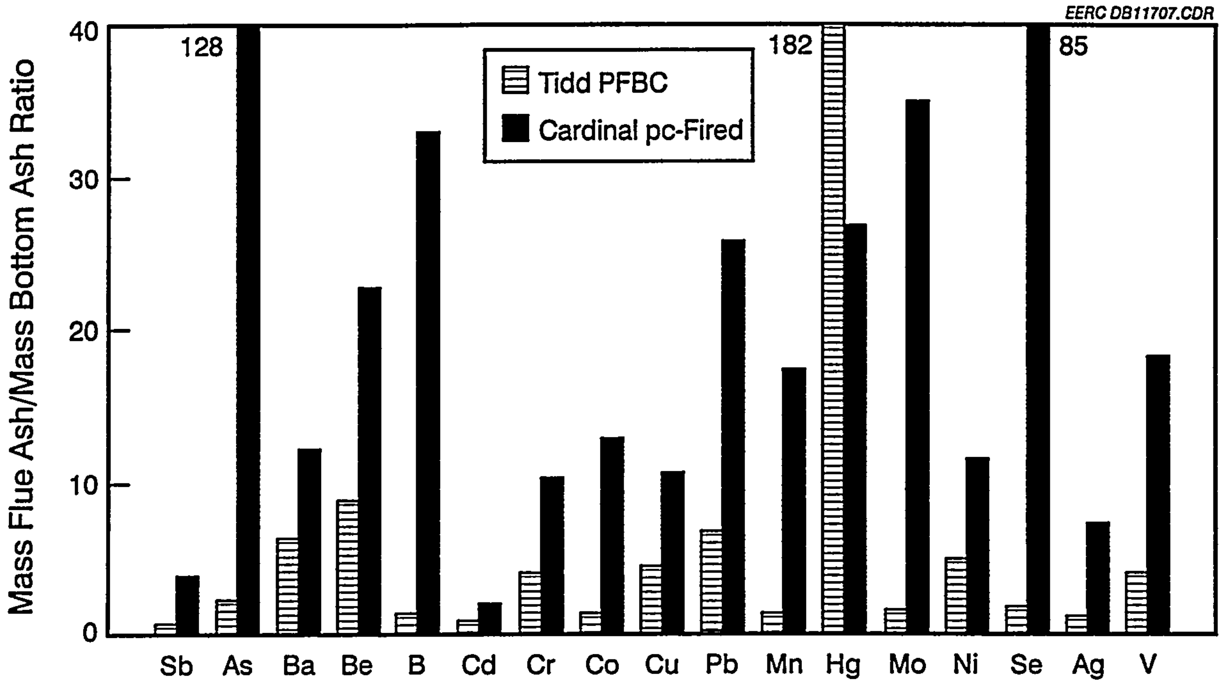

Figure 1. Comparison of the Partitioning of Trace Elements into the Bottom Ash and Flue Gas for the Tidd PFBC and Cardinal pc-Fired System

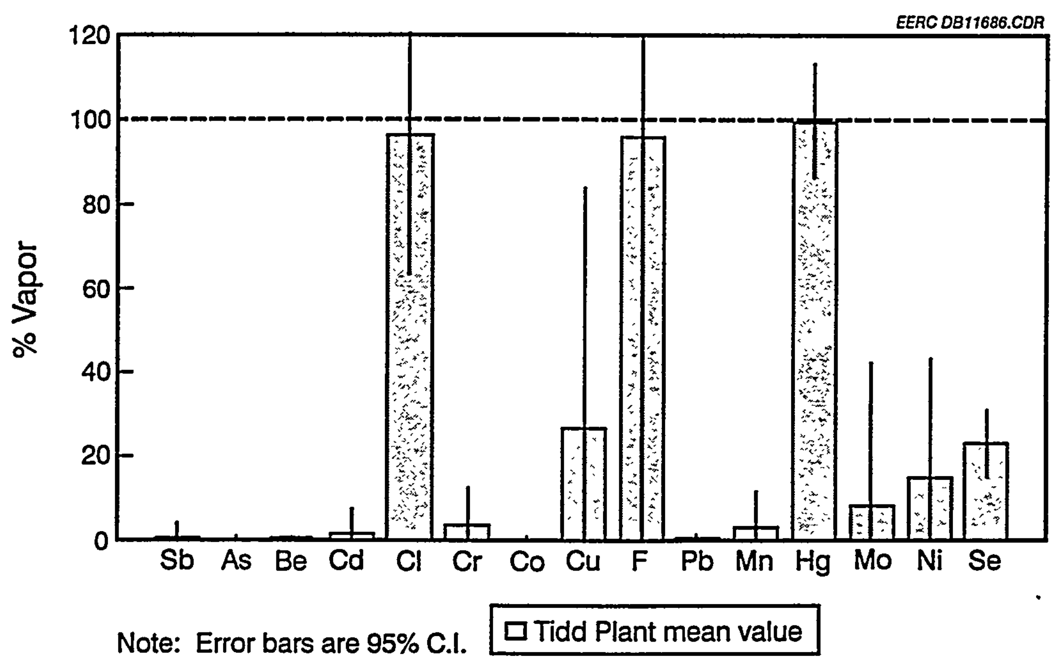

Figure 2. Amount of Trace Elements Present in the Vapor State Exiting with the Flue Gas in the Tidd PFBC

Comparison of Tidd APF and ESP with Cardinal ESP

The efficiency of removing trace elements from flue gases using advanced and conventional control technologies for the Tidd and Cardinal systems is shown in Figure 3. As stated earlier, these two systems burn a similar Pittsburgh No. 8 coal, which allows for easier comparison. The Tidd system has an APF and an ESP, which are both shown on the graph. Th APF shows a higher collection efficiency than the Tidd ESP for all trace elements except As, Cr, Mo, Ni, and Se. As noted in the contractor's report, there is an apparent error in the Ni, Cr, and Mo values of the APF due to contamination from a sampling probe. This results in a lower calculated collection efficiency for Cr, Ni, and Mo in the Tidd APF system. The APF shows a higher or equivalent collection efficiency than the Cardinal ESP except for Sb, Cr, Co, Hg, Mo, and Ni. In general, the Tidd APF was very effective (99.5%) in collecting the material that passed through it; however, the higher operating temperatures allow some elements to remain in the vapor state. Figure 4 shows the amount of each trace element leaving the Tidd APF and Tidd ESP that are present in the vapor state. Most of the trace elements escaping through the APF are in the vapor state, while a significant number escape through the ESP as particulate.

Summary of Conventional and Advanced Power System Collection Efficiencies and Emission Factors

The collection efficiencies and emission factors from the nine conventional plants, as presented in the individual reports, were compared with the emission factors for the APF and HGCU. Since insufficient information was available to calculate the emission factors from the HGCU in its original system configuration, it was decided to calculate the emission factors assuming it was placed after the Tidd PFBC, similar to the location of the APF.

The collection efficiencies for Hg, Se, and all CAAA trace elements are shown in Figure 5 for the average ESP, baghouse, FGD/other, APF, and HGCU. Hg and Se are recognized as the two most difficult trace elements to capture because of their presence in the vapor state at the temperature of collection in conventional systems (300°–400°F). Since advanced systems operate at much higher temperatures (1000°–1400°F), there would be no expected increase in capture due to particle entrapment. The general order of increasing capture of Hg and Se for the five control technologies is as follows:

ESP < APF < FGD/other < HGCU
< Baghouse

The Tidd APF, because of the extreme temperatures, does not collect as much of the Hg and Se as the HGCU or baghouse systems. The HGCU appears to have an absorptive capability with both Hg and Se, even at the higher temperatures. It is possible that the Hg and Se are either physically or chemically captured during the capture of sulfur by the zinc titanate sorbent.

The total collection efficiency for all trace elements on the CAAA list is also shown in Figure 5 for conventional ESPs, baghouses, and FGD/other. The general order of capture for total CAAA trace elements for the five control technologies is as follows:

HGCU < ESP < Baghouse < FGD/Other
< APF

The APF controls the total trace elements very well, since the majority of them are present as particulate, even at the higher temperatures of the APF. The HGCU performed poorly as a

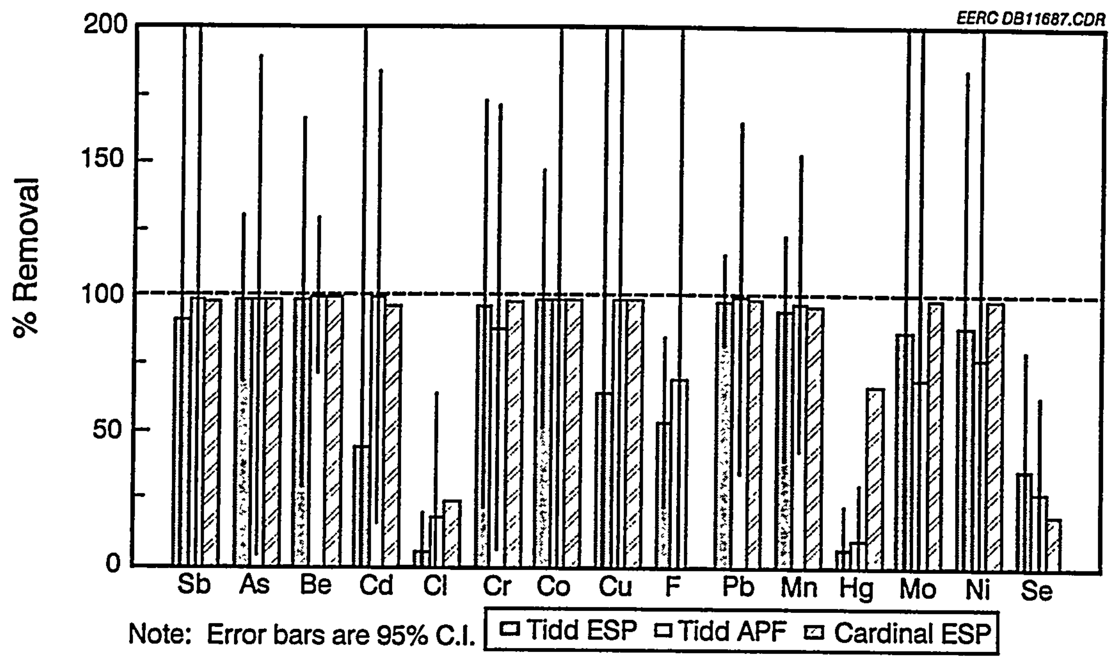

Figure 3. Control Efficiency of Tidd APF, Tidd ESP, and Cardinal ESP

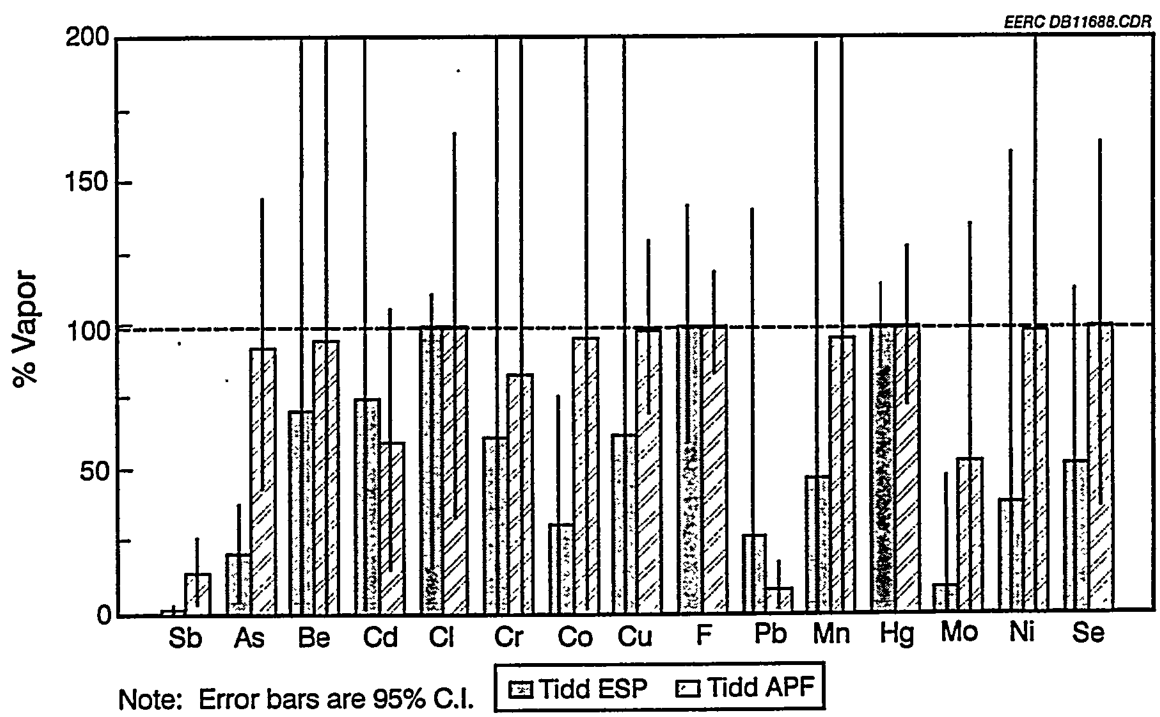

Figure 4. Amount of Trace Elements Present in the Vapor State Exiting with the Flue Gas in the Tidd APF and Tidd ESP

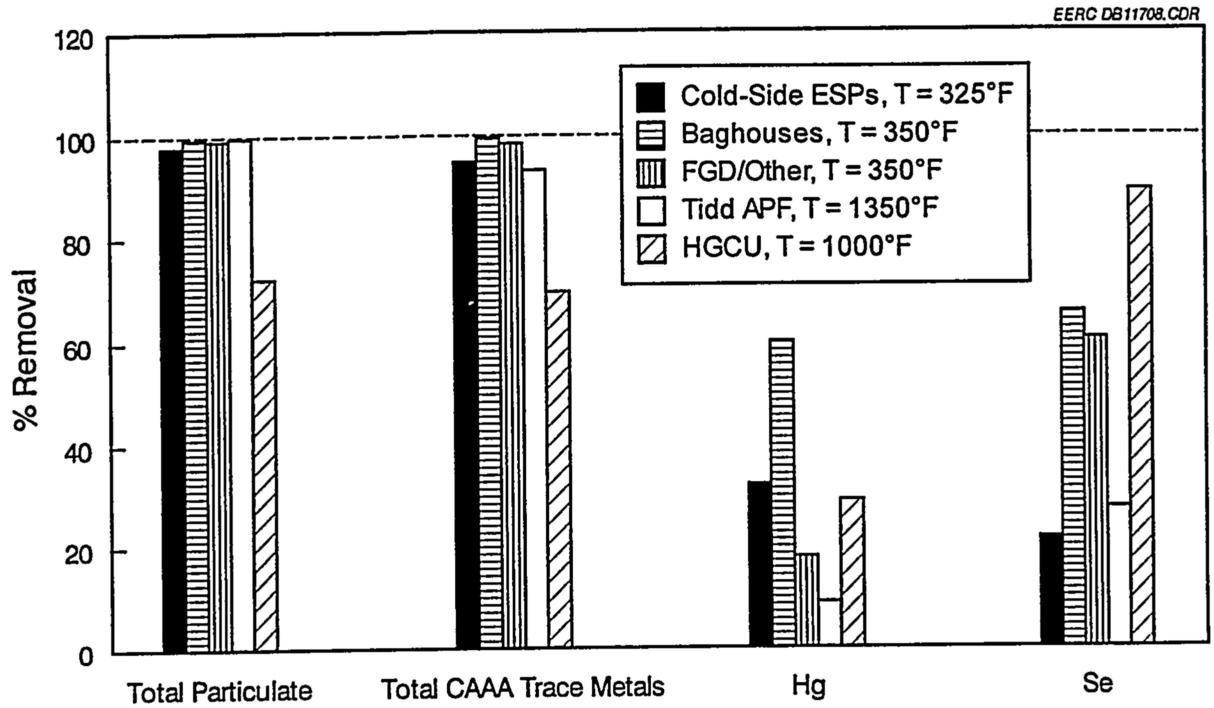

Figure 5. Control Efficiencies for Conventional and Advanced Control Technologies

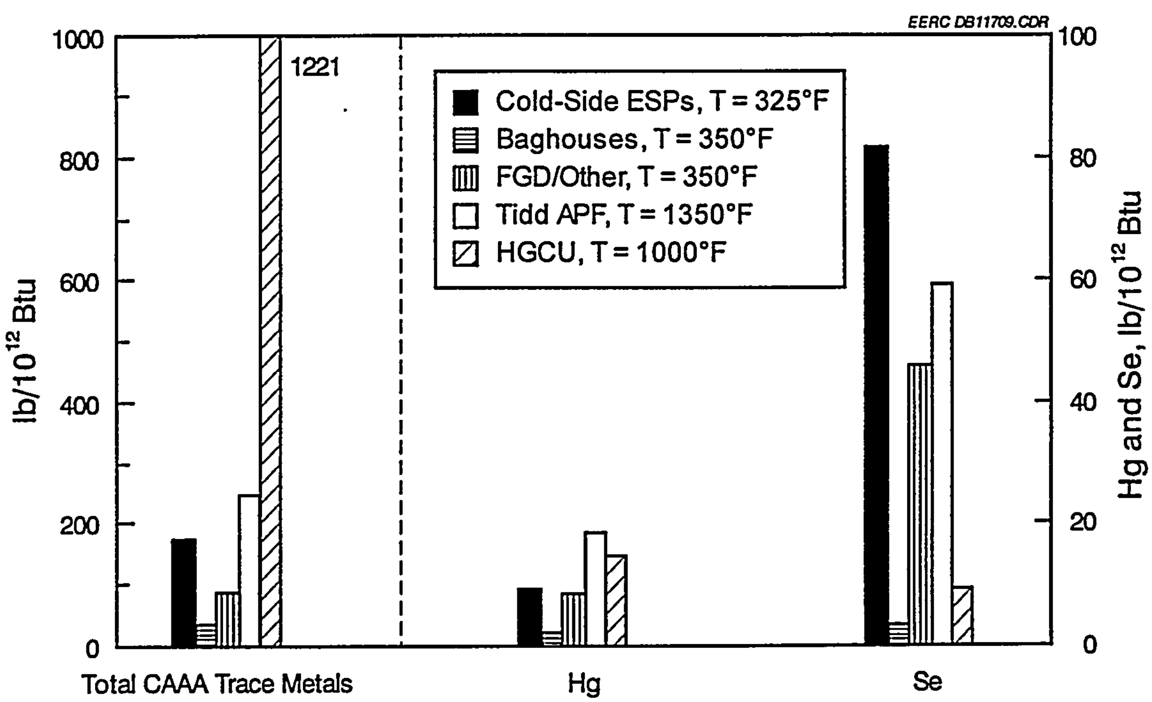

Figure 6. Emission Factors for Conventional and Advanced Control Technologies

particulate control device, even though it performed well for Hg and Se.

Emission factors are summarized for the total CAAA trace elements as well as Hg and Se separately in Figure 6. The results demonstrate that all of the plants studied have fairly low emission factors for total CAAA trace elements on average. It is important to note that the amount of trace elements emitted into the atmosphere is largely a function of the amount present in the coal initially. Therefore, comparisons with different coals are difficult, at best. The Tidd APF, however, shows a higher Hg and Se emission than the others. Although the total is small when compared to other technologies, the political awareness of Hg, regardless of the amount, is important.

FUTURE WORK

The future efforts of this project include 1) inclusion of entrained gasifier data in the study, 2) investigation of potential solid residue regulations, and research in current and new control technologies for advanced systems. Data from the Texaco Coolwater and Louisiana Gasification Technology, Inc., systems are being studied. Potential utilization and disposal requirements for advanced power systems will be explored with reference to existing and future regulations. The potential to enhance trace element capture through enhancement of current control technologies or development of new technologies will also be explored.