Mercury Emissions - Trends and Control Effectiveness

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INTRODUCTION

Emissions of mercury from municipal waste combustors has been an item of interest in the 1990's. Standards have been established by the USEPA[1] (MACT Standard) and by state regulatory agencies such as the New Jersey Department of Environmental Protection[2]. As the owner and operator of facilities that combust over 3.5 million tons per year of municipal waste, American Ref-Fuel has been very active in following the trends in waste mercury content, promoting the recycling of mercury containing wastes, and understanding and applying technologies to minimize mercury emissions from waste combustors.

Mercury emissions from waste combustors is determined by the mercury content of the waste stream, combustion efficiency, and the efficiency of the air pollution control equipment at removing mercury. In this paper we review some encouraging trends in waste mercury levels, and discuss the performance of several different combustor/air pollution control configurations for controlling mercury emissions.

CONCERN ABOUT MERCURY IN WASTE

Concern for mercury in the environment was highlighted in Clean Water Action's 1990 report termed Mercury Rising[3]. The principal argument in the report was that MSW incinerators emit mercury to the atmosphere and that mercury then enters the food chain, thereby increasing the potential health effects due to biomagnification. In this vein, another study[4] found increased levels of mercury in sphagnum moss near a Waste-to-Energy facility. Other studies[5] have placed modern atmospheric deposition rates and sedimentation rates at 3-4 times historical rates, with fresh water lake accumulation being proportional to catchment surface area.

In response to these and other studies, the United States Environmental Protection Agency commissioned a characterization study[6] on mercury containing wastes for the period 1990 to 2000, and the New Jersey Department of Environmental Protection established a Task Force on Mercury Emissions. The NJDEP Task Force report[2] and USEPA study[6] both listed batteries as the principal mercury-containing waste source today. The USEPA study concluded that mercury in waste peaked in 1986 (estimated at 770 tons) and would continue on a downward trend to the year 2000 (to an estimated 173 tons), based primarily on the removal of mercury from alkaline batteries and the elimination of mercury-based biocides in paints, for an overall reduction of over 70%. While we are on a definitive downward trend in mercury use, there will be individual product increases, such as mercury-containing fluorescent bulbs and mercury switches. New product applications, like sneakers with mercury switch activated lights, may also alter the dynamics of the decline.

American Ref-Fuel has seen the results of these mercury reduction efforts at its facility in Essex County, New Jersey. Figure 1 presents the change in uncontrolled mercury levels in the flue gas exiting the boilers, prior to the air pollution control equipment, from 1990 to 1996. In 1990 and 1991, the uncontrolled mercury averaged about 600 μg/dscm, and ranged from about 300 to over 1100 μg/dscm. In 1996, the uncontrolled mercury had dropped significantly, averaging about 200 μg/dscm, and ranging from about 100 to 300 μg/dscm. (Note that all mercury concentrations presented throughout the paper are at 7% O_2.) While Ref-Fuel had developed and implemented a battery recycling program in Essex

County over this time period, the primary cause for this dramatic decrease is believed to be due to decreased mercury entering the waste stream, particularly from batteries. Battery manufacturers have sought to reduce the mercury content in batteries due to public pressure and legislative initiatives like New Jersey's. This downward trend in uncontrolled mercury levels has also been seen in data from other American Ref-Fuel facilities, although the trend is less pronounced and the database is less extensive.

MERCURY CONTROL IN MODERN WASTE-TO-ENERGY SYSTEMS

American Ref-Fuel operates five large municipal waste combustors in the United States employing a number of different combustion and air pollution control technologies. Reviewing the mercury emissions from these facilities illustrates the importance of both the combustor design and the type of air pollution control equipment, in determining the mercury control performance.

Ref-Fuel's first three facilities employ Deutsch Babcock's center-flow combustor design (see Figure 2) and operate with approximately 90% excess air. The air pollution control technologies, however, differ in each facility, as follows:

Essex, NJ	-	SDA / ESP
Hempstead, NY	-	SDA / Reverse-Air FF (low air/cloth ratio)
SE Connecticut	-	SDA / Pulse-Jet FF (high air/cloth ratio)

The average mercury emission and control performance of each of these facilities is presented in Figure 3. While these are commercial facilities, and do not operate identically, they do employ the same furnace design and boiler configuration, and operate with similar combustion conditions and SDA temperatures, which are thought to be the most important operating parameters affecting mercury control. The difference in mercury control between the facilities is believed to be primarily due to the different air pollution control technologies, which is consistent with the current industry knowledge. The SDA/ESP at Essex yields the worst performance, with mercury emissions averaging greater than 200 μg/dscm, and mercury reduction across the air pollution control equipment of about 65%. (This facility recently installed a supplemental mercury control system which will be discussed below.) The reverse-air fabric filter (RA-FF) at Hempstead achieves the best performance, with mercury emissions of about 30 μg/dscm, and reductions of about 95%. This performance rivals that of carbon enhanced systems, and easily meets MACT standards of 80 μg/dscm emission or 85% reduction. This superior mercury control performance is believed to be due to a combination of the large fabric filter, and the quantity and nature of the residual carbon on the fly ash. SE Connecticut, with the smaller pulse-jet fabric filter (PJ-FF), also performs well with mercury emissions of about 60 μg/dscm, and reductions in excess of 80%, but is inferior to the larger reverse-air system at Hempstead.

American Ref-Fuel's SEMASS facility, in Rochester, Massachusetts, provides another comparison of the SDA/FF vs. SDA/ESP for mercury control. The SEMASS facility contains three units, all with the shred-and-burn technology developed by Energy Answers Corporation. Two of the units have SDA/ESP air pollution control systems, while the third unit, which was constructed more recently, has an SDA/FF system. While mercury reduction data is not available for all three units, a comparison of the mercury

emission levels again shows SDA/FF systems to be superior to SDA/ESP systems. The unit with the SDA/FF averages mercury emissions of about 20 μg/dscm, while the SDA/ESP units averages about 75 μg/dscm.

American Ref-Fuel's facility at Niagara was recently retrofitted with a new combustor, boiler, and air pollution control system. The combustor is Deutsch Babcock's new parallel-flow design (see Figure 4), which operates with just 60% excess air, and is designed for increased turbulence in the combustion zone relative to the center-flow design. The higher combustion temperature resulting from the reduced excess air, coupled with the improved mixing, result in improved combustion efficiency and lower residual carbon on the fly ash exiting the boiler. The new air pollution control system at Niagara is a SDA/reverse-air fabric filter, with a low air/cloth ratio, similar to that at Hempstead. The strategy in using this design was to seek to achieve the superior emissions control, including mercury, that was demonstrated at Hempstead.

The actual mercury control performance for the retrofitted Niagara facility, however, has turned out to be quite poor. The average mercury emissions and control performance for this new facility is presented in Figure 5, and compared to that of Hempstead. The average mercury reduction across the SDA/RA-FF at Niagara averaged just 35%, and the mercury emissions averaged about 170 μg/dscm. This is considerably worse than the 95% reduction, and 30 μg/dscm emission achieved at Hempstead. The reason for this poor mercury control performance is believed to be due to the reduced, and possibly altered carbon content (due to the higher combustion temperature) of the fly ash at Niagara. Although based on a very limited database, analysis of the carbon content of Niagara fly ash shows it to be about 25% less than that of Hempstead. This alone, however, does not seem significant enough to explain the large difference in mercury control between Niagara and Hempstead. The chemical form of the mercury in the flue gas is also known to affect its adsorption potential on the carbon containing fly ash[7]. The different furnace and boiler configuration at Niagara may alter the speciation of mercury containing compounds in the flue gas entering the SDA/RA-FF, affecting its propensity for removal. However, no data has been collected to support this theory. The new Niagara facility is currently undergoing an evaluation for the addition of a supplemental mercury removal system to reduce the mercury emissions to less than MACT standards.

SUPPLEMENTAL MERCURY CONTROL TECHNOLOGY

While several technologies have been developed and tested to improve the removal of mercury in the primary air pollution control equipment, the injection of powdered activated carbon provides the best fit with the SDA/FF and SDA/ESP systems commonly used in the United States, achieving high mercury reduction at an affordable cost of approximately $1 per ton of MSW. Activated carbon injection has been identified as the Best Available Control Technology by the USEPA, and has been repeatedly demonstrated in tests and commercial applications to easily meet the MACT standards of 80 μg/dscm or 85% reduction. American Ref-Fuel has followed the development and commercialization of activated carbon injection for mercury control, has tested the effectiveness of various methods of carbon injection in their facilities, and has recently installed a commercial system in their Essex County facility.

In the early 1990's, American Ref-Fuel tested two methods of activated carbon injection at its Essex facility. In the first method, the activated carbon was injected "wet", by adding it to the lime slurry being sprayed into the SDA units. The second method injected the carbon "dry", by adding it in powdered form to the flue gas exiting the boiler, upstream of the SDA units. At about the same time, similar tests were being conducted by the USEPA at the Stanislaus County, California facility[8], which employs an SDA/FF system, and at the Camden County, New Jersey facility[9], which uses an SDA/ESP system similar to Essex. The results of these tests provide an interesting comparison of "wet" versus "dry" carbon injection in these different air pollution control systems.

Figure 6 presents mercury reduction data from the three tests for "wet" carbon injection. In the SDA/FF system at Stanislaus, mercury reductions ranging from about 83 to 97% were achieved at carbon injection rates between 60 and 100 mg/dscm. Essex and Camden, with similar SDA/ESP systems, yielded similar mercury reduction performance, but as expected, were inferior to the Stanislaus SDA/FF performance. Essex and Camden achieved only 70 to 80% mercury reduction at carbon injection rates of 80 to 90 mg/dscm.

Figure 7 presents mercury reduction results from the three systems for "dry" carbon injection. Although the data is very scattered at low carbon injection rates, at carbon rates above 50 mg/dscm the SDA/FF system again showed superior performance, with mercury reductions ranging from 88 to 98%. The SDA/ESP system at Essex was only able to achieve 78 to 89% mercury reduction at higher carbon rates of about 90 mg/dscm.

A comparison of the "wet" and "dry" injection results at Stanislaus (Figures 6 and 7, respectively), shows little difference in the mercury reduction performance with their SDA/FF system, as was concluded from the study[8]. However, this was not the case in the SDA/ESP systems at Essex and Camden. Figure 8 presents the "wet" and "dry" carbon injection results for both Essex and Camden. "Dry" carbon injection achieved significantly better mercury reduction performance in these SDA/ESP systems, reaching reductions of about 95% at carbon rates above 200 mg/dscm. While this carbon injection rate is significantly higher than that needed in the Stanislaus SDA/FF system, it does demonstrate that high mercury reductions can be achieved in SDA/ESP systems with "dry" carbon injection. "Wet" carbon injection at Essex and Camden was limited to between 80 and 90% mercury reduction, even at carbon rates above 200 mg/dscm, leaving some doubt as to whether "wet" injection in a SDA/ESP system can consistently meet the MACT standard of 85% mercury reduction. Some industry sources have reported that "wet" injection of carbon with enhancers may perform similarly to "dry" injection systems. If proven true, this may change the relative performance of "dry" vs. "wet" in SDA/ESP systems.

The results of these analyses formed the basis of American Ref-Fuel's evaluation to find the best carbon injection method for a permanent system to be installed at Essex last year. The system installed is a "dry" carbon injection system designed by Norit Americas, Inc. The system is designed to pneumatically convey and inject the activated carbon directly into the side wall of the SDA unit. The system has been in operation since January 1996, and performance to date has been very good, allowing the carbon injection rate to be optimized to maximize both mercury reduction and carbon utilization. The system has achieved 90 to 95% mercury reduction, and emissions of less than 15 μg/dscm, at carbon injection rates of about 75 mg/dscm[10].

SUMMARY AND CONCLUSIONS

The available data suggest that facilities equipped with dry injection activated carbon systems, as part of an SDA/FF or SDA/ESP can easily achieve the MACT standards of 85% mercury reduction or 80 μg/dscm mercury emission. While a number of factors influence the emissions of mercury from a waste-to-energy facility, reverse-air fabric filters appear to have slightly better mercury removal performance when compared to pulse-jet fabric filters, and both types of fabric filters are superior to ESP equipped facilities. The relative performance of the Hempstead and Niagara facilities suggests the importance of the combustor configuration, in conjunction with the air pollution control equipment, for determining mercury control. Improved combustor designs with higher combustion temperatures and better mixing, yield higher combustion efficiency and lower residual carbon on the fly ash, which negatively impacts mercury control in the downstream fabric filter. The mercury control in these more modern designs can easily be recovered, however, by adding a dry injection activated carbon system. Ultimately, facility designers may find a combustor/air pollution control configuration that achieves good combustion and minimal mercury emissions, without requiring the addition of activated carbon. Combustion efficiency and residual carbon quantities alone do not appear to explain the differences between Niagara and Hempstead; other factors related to carbon or mercury speciation may explain more with regard to removal dynamics.

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FIGURE 1
Downward Trend in Uncontrolled Mercury at Essex County

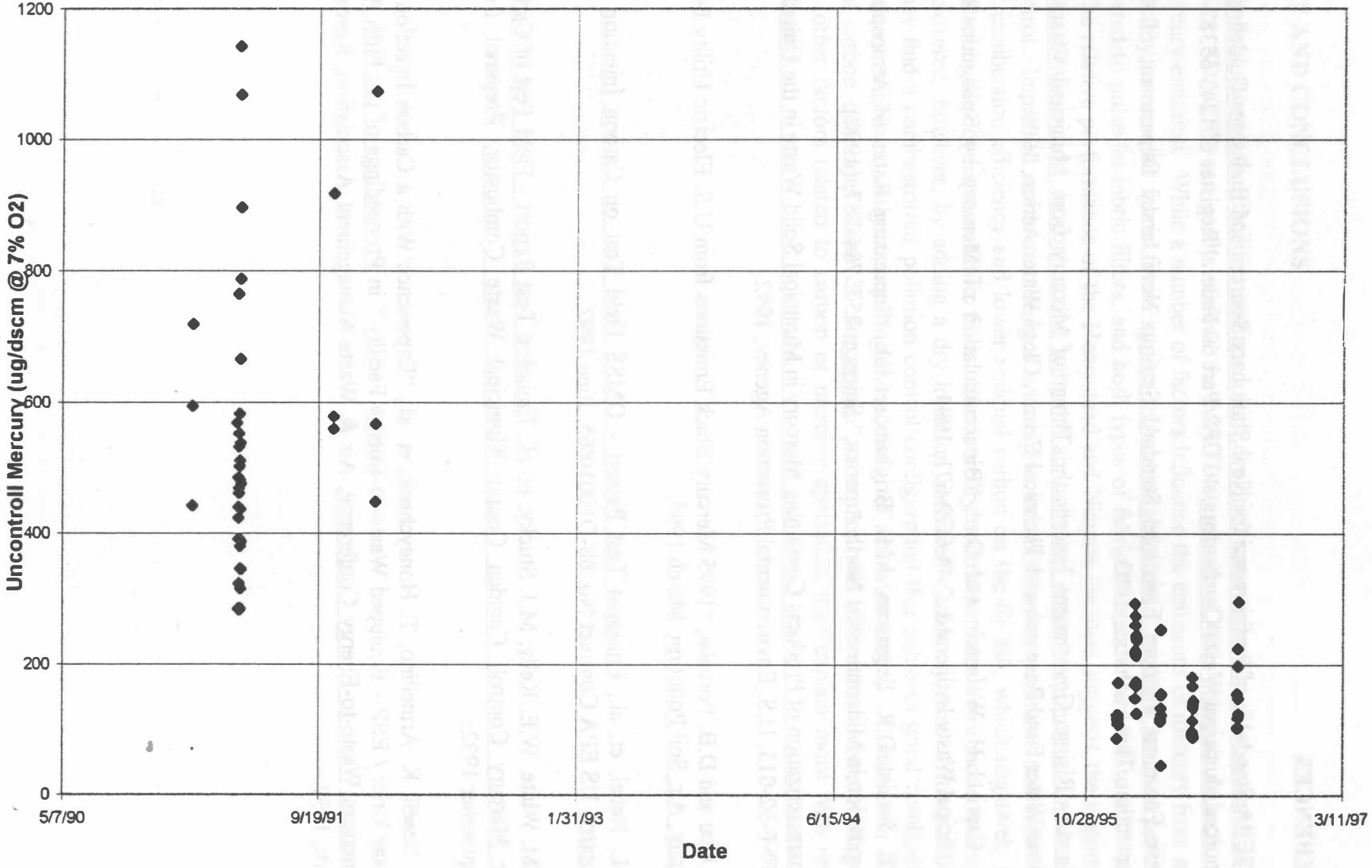

Figure 2
Center-Flow Combustor Design

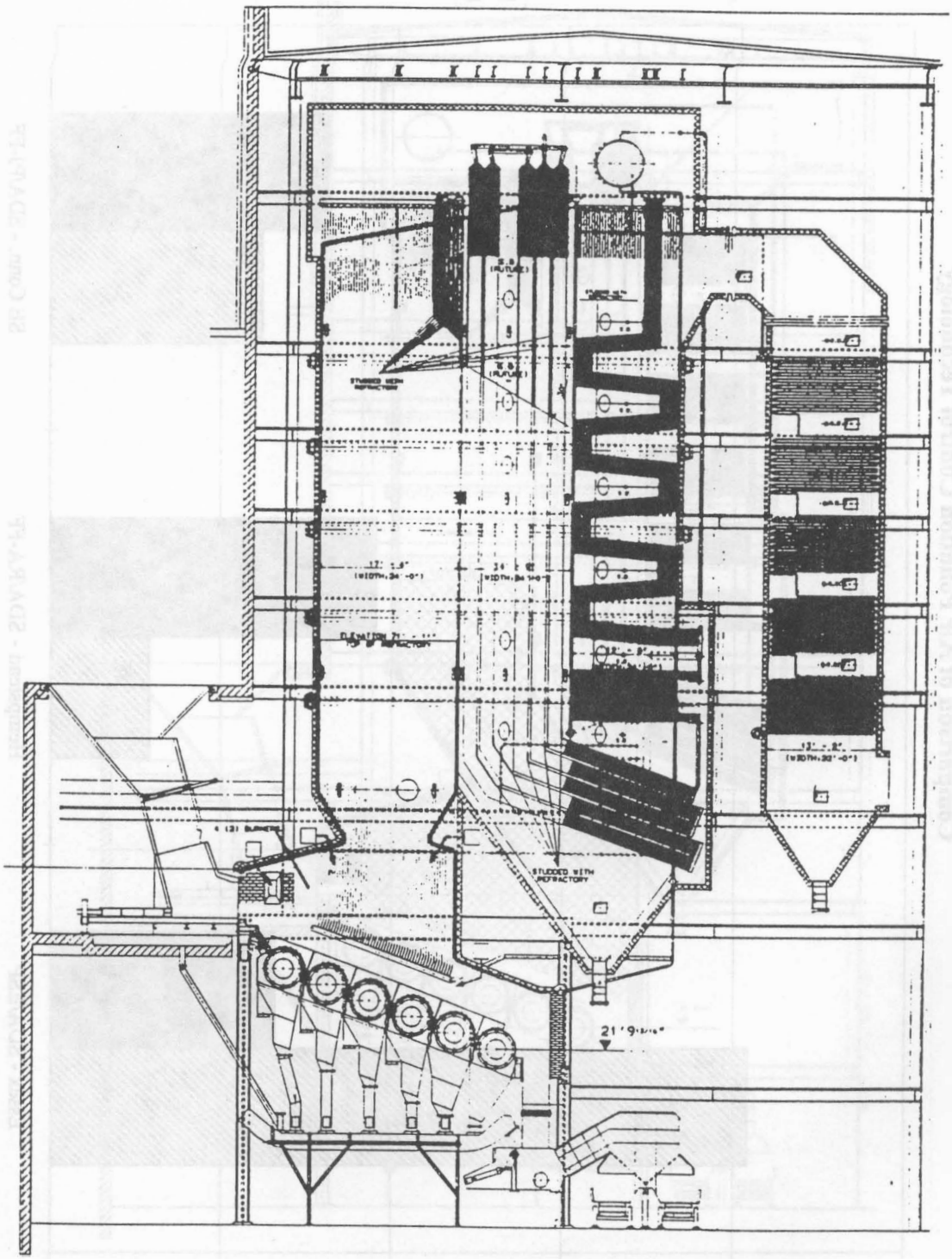

FIGURE 3
Comparison of Air Pollution Control Technology

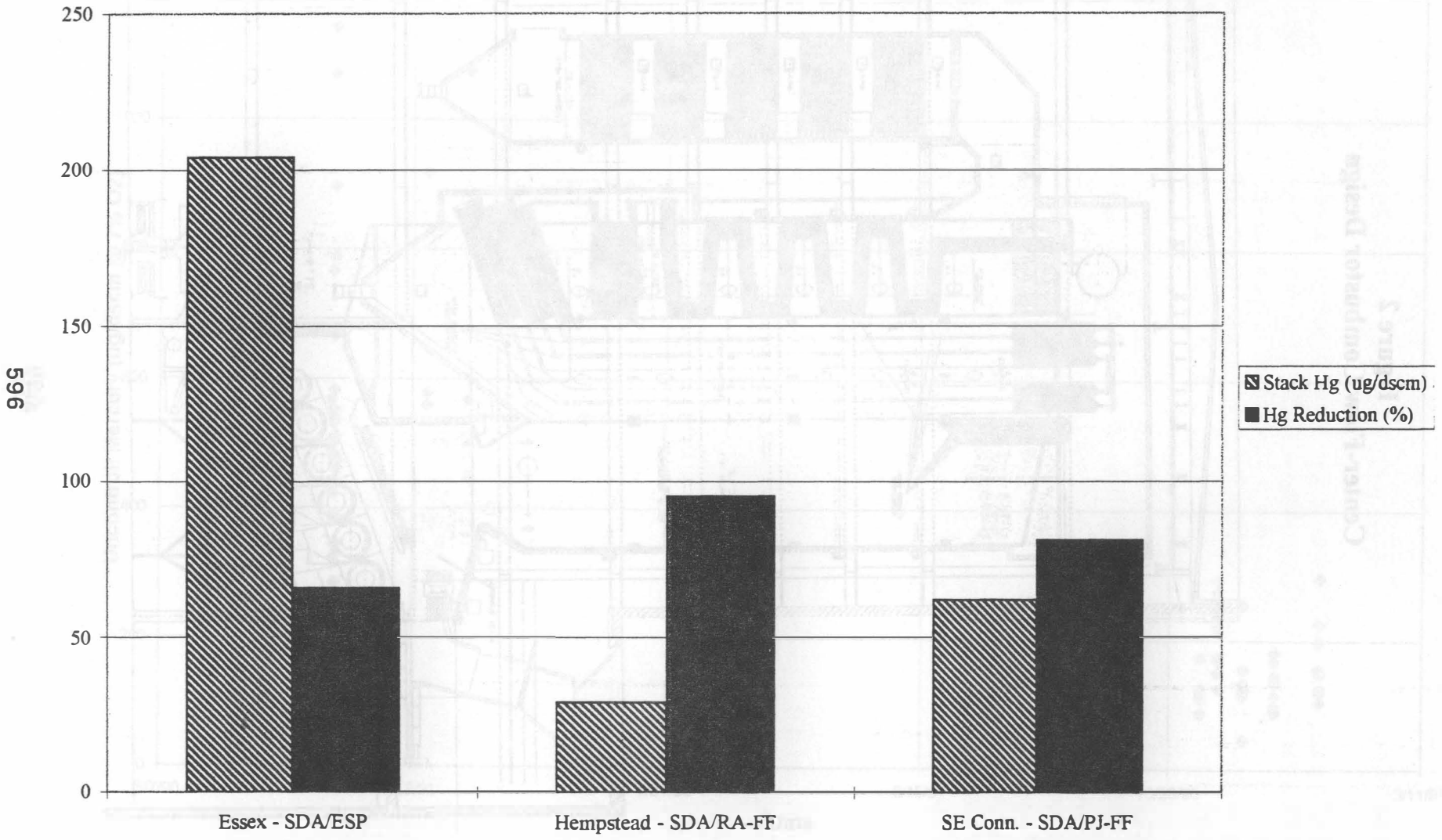

Figure 4
Parallel-Flow Combustor Design

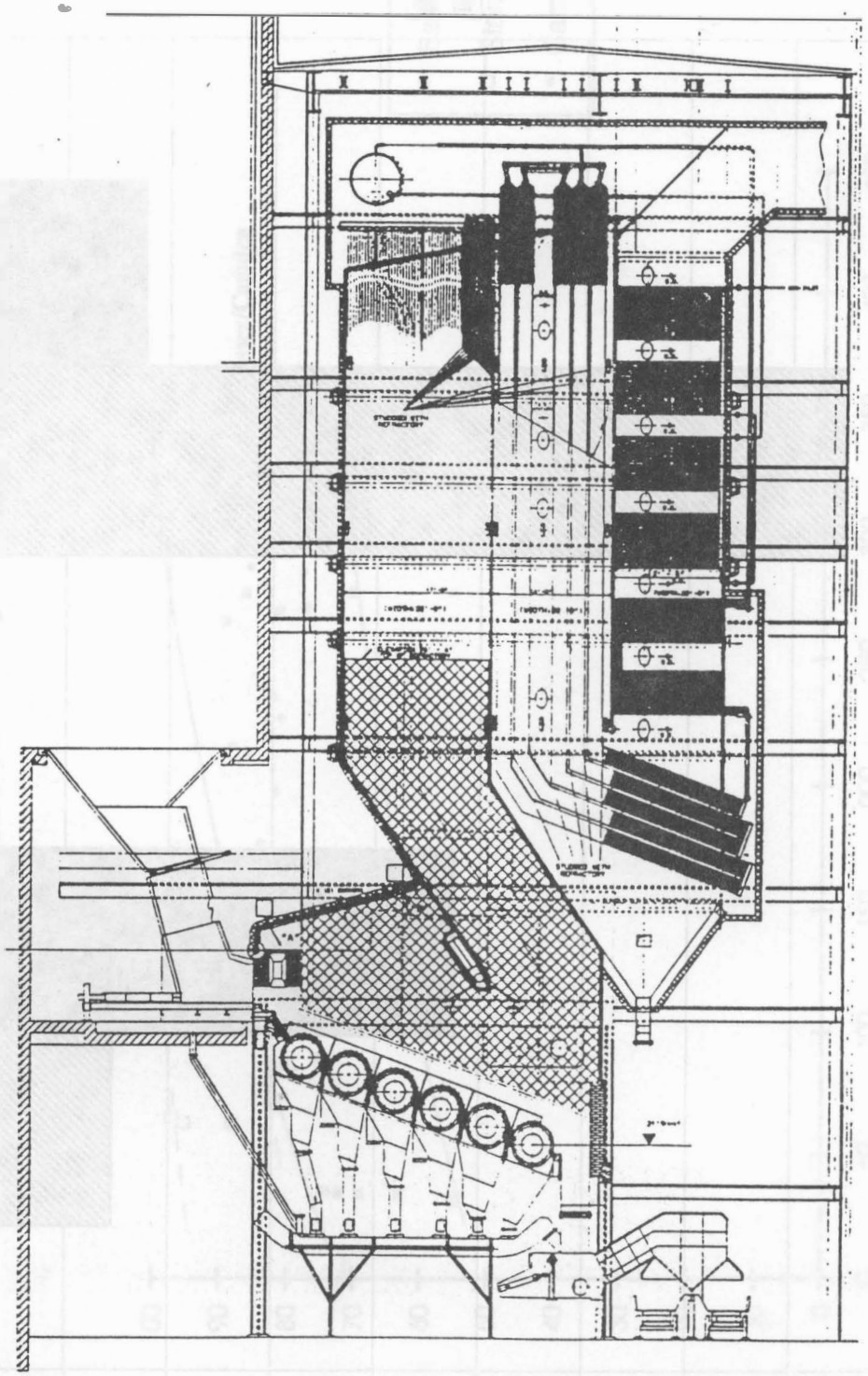

FIGURE 5
Comparison of Combustor Technology

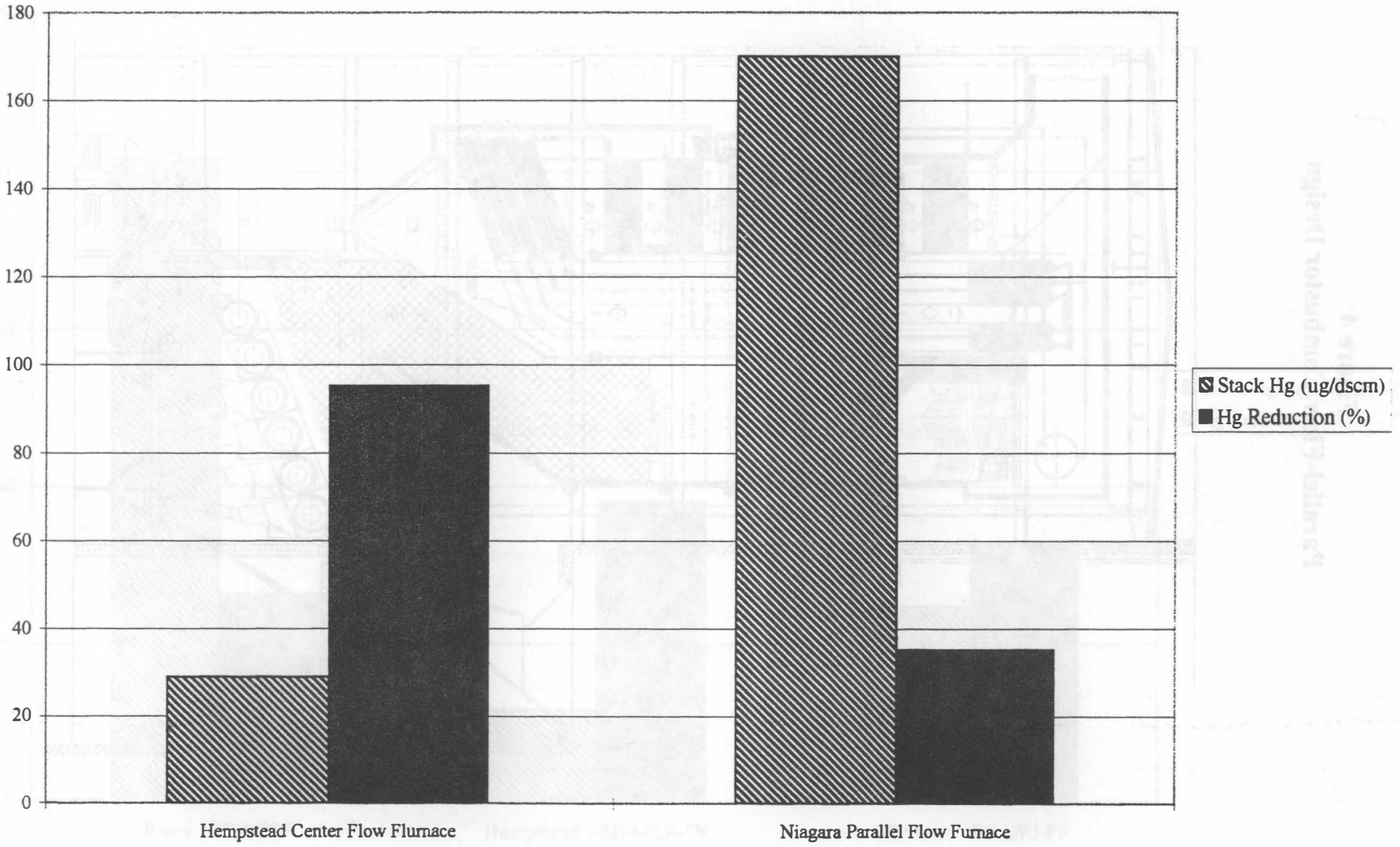

Figure 6
"Wet" Activated Carbon Injection Performance Data

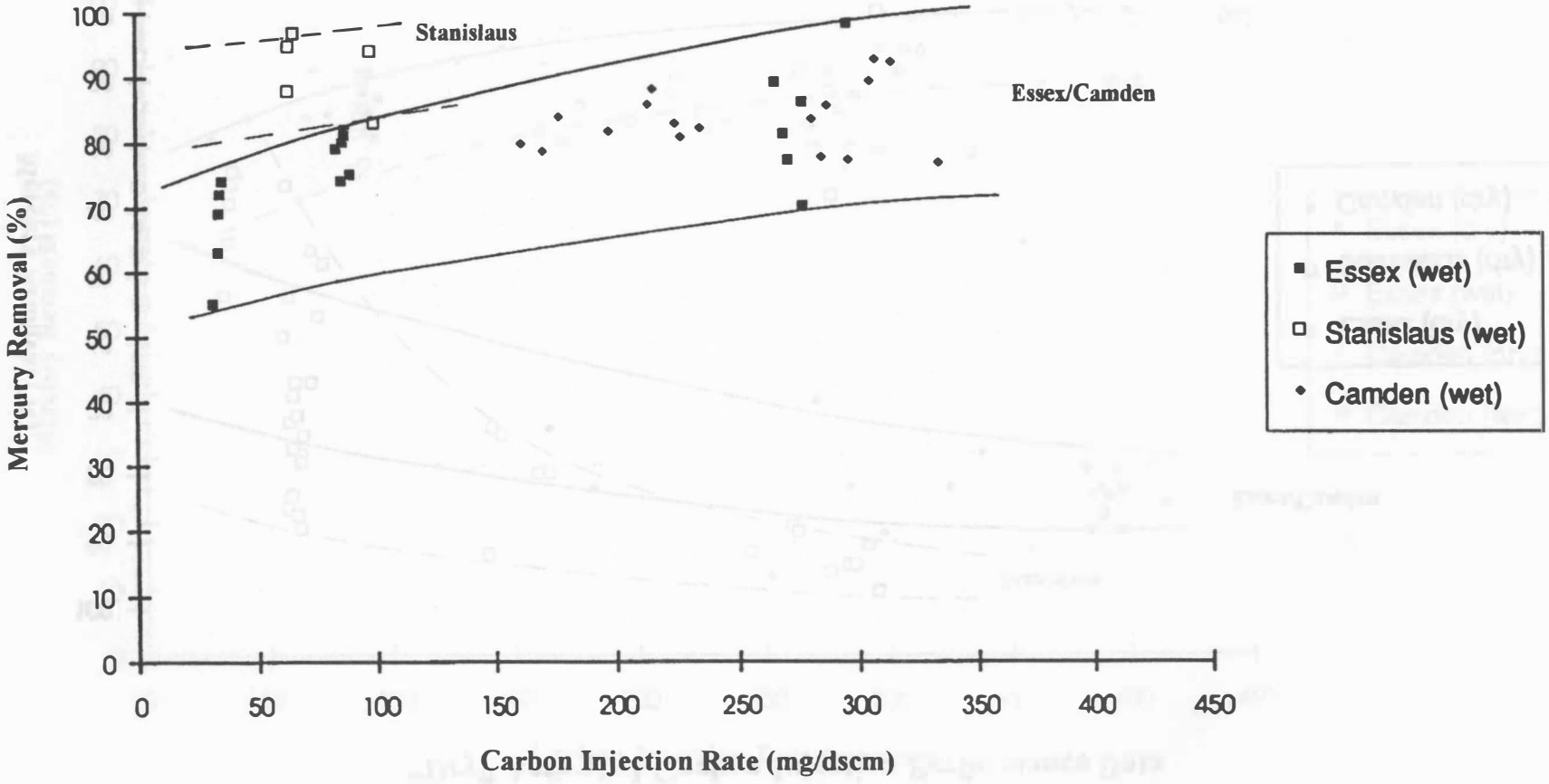

Figure 7
"Dry" Activated Carbon Injection Performance Data

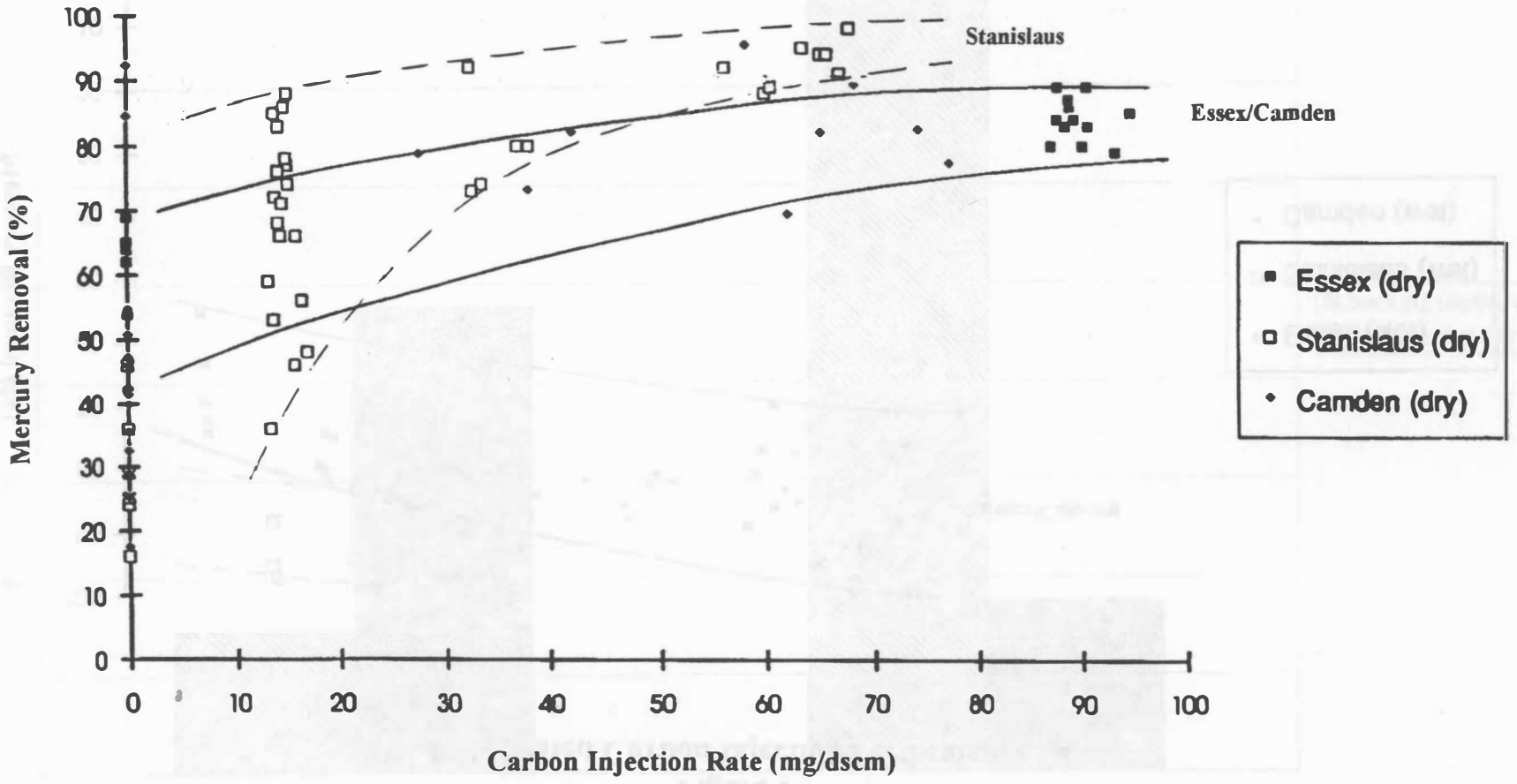

Figure 8
Comparison of "Dry" and "Wet" Carbon Injection for SDA/ESP Systems