Experience with a Carbon Injection System at a Spray Dryer/Electrostatic Precipitator Equipped Waste-to-Energy Facility

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INTRODUCTION

American Ref-Fuel Company of Essex County obtained an air permit to construct the Essex County Resource Recovery Facility (ECRRF), a municipal solid waste resource recovery facility, in December 1985 from the New Jersey Department of Environmental Protection (NJDEP). Permit condition A.9.a. states that the emission rate of mercury from each unit shall not exceed 0.053 pounds per hour, based on the average value of three runs using EPA Method 101A. Testing for mercury was required to be performed on a quarterly basis during the facility's first year of operation. This emission requirement was met by the spray dryer adsorber (SDA)/electrostatic precipitator (ESP) equipped facility. Subsequently, the NJDEP chartered a task force to investigate the setting of a new statewide mercury emission standard for municipal solid waste (MSW) combustors. The task force in July of 1993 recommended a more stringent two phase emission standard requiring all facilities to achieve 65 ug/dscm at 7% oxygen dry volume or 80 % reduction by January 1, 1996, and to achieve 28 ug/dscm at 7% oxygen dry volume or 80% reduction by January 1, 2000. These recommendations and a requirement for installing a mercury control system were codified into a regulation in November 22, 1994. In order to comply with the new regulation the facility proceeded with a retrofit mercury control system.

FACILITY DESCRIPTION

The Essex County Waste-to-Energy Facility is New Jersey's largest waste-to energy plant, owned and operated by American Ref-Fuel of Essex County in Newark. In operation since late 1990, it serves the refuse disposal needs of 22 municipalities in Essex County and the surrounding region. The plant has three combustors which operate 24 hours per day, 365 days per year, and processes approximately 2,500 tons of municipal solid waste per day. The plant also produces, via two steam turbine-generators, about 70 megawatts of electricity for sale to Public Service Electric and Gas, New Jersey's largest utility.

Each incinerator utilizes the proprietary mass burn technology developed by the German firm of Deutsche Babcock Anlagen (DBA), which since 1961 has been installed in more than 60 facilities worldwide. Each unit at the Essex plant has six Duesseldorf roller grates, each with a width of 6.5 meters. The heat generated by the refuse combustion is used in a four pass boiler to produce steam of 650 psia and 750F. The flue gas generated by the combustion leaves the final economizer section of the boiler at a temperature between 432F to 520F, depending upon the degree of boiler surface fouling.

Each incinerator has a dedicated flue gas cleaning system, composed of two spray dryer absorbers (SDAs), or "dry scrubbers", in parallel, followed by an electrostatic precipitator (ESP). The system was supplied by Deutsche Babcock Anlagen. The flue gas flow from the economizer outlet, approximately 110,000 to 150,000 scfm wet, splits into two parallel streams that enter the SDAs at the bottom. In this inlet section, called the pre-cyclone, approximately 70% of the flyash is removed from the flue gas flow. The gas then flows upward through pipes which dampen the remaining turbulence into the main reactor vessel. Dual fluid nozzles deliver a lime slurry of approximately 15% concentration into the reactor vessel, using compressed air for atomization. The lime reacts with the acid gas components to form neutral salts of reaction that are collected in the SDAs and downstream in the electrostatic precipitator. The outlet concentration of SO_2 is the parameter that is used to determine the lime slurry feed rate. As the flue gas exits the SDAs at the top, the temperature is measured and additional dilution water is injected via the dual fluid nozzles to maintain the outlet temperature between 280^{o}F to 325^{o}F. Each

SDA is 105 feet tall with an internal diameter of 12 feet 2 inches. Upon exiting the SDAs, the two flue gas streams are combined and enter an ESP. These particulate collection devices used at the Essex Facility were supplied by DBA through subsupplier Flakt, Inc. Each ESP has three fields and has a particulate emission requirement of 0.015 grains per dry standard cubic foot at 7% O_2.

EMISSION HISTORY

The ECRRF was required as an initial permit condition to perform mercury testing, using Method 101A, along with a variety of other parameters on a quarterly basis during the first year of operation. Although the facility initially had one of the lowest mercury emission concentration rates in the state, it did not achieve the required emission rate of 0.053 pound per hour. As a result, additional monthly testing was mandated which demonstrated the facility's compliance with its mercury emission rate. In order to settle any claims related to prior compliance within the mercury emission rate, an Administrative Consent Order was entered into between the ECRRF and the NJDEP on January 14, 1994. This ACO required additional testing on a quarterly basis utilizing Method 29. Figure 1 presents the data from these test programs, all prior to any mercury control system being installed at the facility.

Before the NJDEP revised the statewide mercury emission requirements, the facility and the State of New Jersey had undertaken a number of actions to reduce mercury levels in the wasteshed. Some of these programs are discussed in greater detail in the two papers cited in the Reference section of this paper. The facility began a battery survey program designed to eliminate mercury batteries from the waste stream. Mercuric oxide batteries were commonly used in consumer items such as hearing aids, in institutional applications such as hospitals and in military applications. In addition, New Jersey passed the Dry Cell Battery Management Act which was intended to restrict mercury containing batteries in the state. Fluorescent light bulb recycling was also promoted by the facility and certain counties. As can be seen from the data presented in Figure 1, mercury emission rates were trending downward.

FACILITY MERCURY RETROFIT

In order to meet the new mercury requirements, bids were solicited from suppliers of systems that could inject carbon into the flue gas stream. Although a reduction in mercury concentration was the prime objective, a reduction in dioxin was also anticipated. Concerns were raised that performance would be more difficult to achieve with an ESP-equipped facility or that other emission concerns such as increased particulate might arise. Bids were accepted on a dry carbon injection system, on a carbon in water slurry system that mixes the carbon slurry with the lime slurry for injection through the existing dual fluid nozzles, and for a system in which carbon is added to the lime slurry tank and the combined lime/carbon slurry is injected via the existing dual fluid nozzles into the reactor vessel. The system chosen was a dry carbon injection system supplied by Norit Americas Inc. Some testing and data appear to indicate that a dry injection system is more efficient in carbon utilization, which is the major cost in a life cycle analysis of this system.

The Norit Americas Inc. powdered activated carbon, bulk storage and dosing system is composed of a bulk storage silo and three independently controlled dosing modules with associated carbon delivery piping. The system layout is shown in Figure 2. Fitting the system on the existing site posed numerous challenges. A decision was made to locate this system near the existing lime storage silos and lime slakers, and the phosphoric acid tank in order to keep bulk chemical storage in a centralized but accessible part of the plant. This decision, along with the required traffic patterns and access roads at this operating plant led to the layout shown. Air is blown by the blowers from the auxiliary building to eductors in the silo skirt. There carbon is entrained within the air stream and subsequently is conveyed to the flue gas streams in the plant.

The total volume of the carbon silo is approximately 5,000 ft^3, and can contain 2-1/2 truckloads (more than a month's usage) of carbon while maintaining 13 feet of freeboard. The silo is fed from road tankers carrying 40,000 pounds per truck. During silo filling, the carbon is pneumatically conveyed from the truck to the silo. The silo is equipped with three point level switches, and with one continuous level sensor. A bin vent filter is mounted atop the silo to minimize fugitive emissions during silo filling. In addition, the silo has two 39 inch x 40 inch blow-out panels based upon the National Fire Protection Association NFPA 68 requirements.

Figure 3 shows a schematic of the carbon dosing and supply systems. The silo skirt contains various components with the remainder located within the auxiliary building. Ten air fluidization nozzles are connected to each of the three discharge cones to promote the flow of carbon. For each of the three lines, carbon flows from the silo through a rotary valve to a volumetric feeder package. These packages contain a 6.0 ft^3 feeder supply hopper with three level switches and volumetric feeders with a variable speed controller allowing a 50:1 turndown. Adjustments in carbon feed rate can be made over a range of 0 to 150 pounds per hour. The carbon discharges from the volumetric feeder into a pneumatic conveying eductor where carbon is entrained within the air stream. Low pressure air is used as the motive force to convey the carbon to the point of injection into the flue gas stream.

Figure 4 shows a layout of the auxiliary building, which was designed for easy access to components requiring maintenance. A monorail and hoist were subsequently added to aid in blower and motor removal and maintenance. Each positive displacement blower is equipped with a single speed motor, and delivers 160 scfm air at 12 psig. Other equipment located within the auxiliary building include an air receiver for system instrumentation, motor control centers, and a main control panel. The original design concept was to have PLCs to monitor and control all system functions. However, a change was made to control the system from the plant main distributed control system (DCS) with local indication provided by Norit.

After the carbon is entrained within the air stream by the eductors it is conveyed through a piping system composed of schedule 40 carbon steel pipe with ceramic backed, 24" centerline radius sweeping elbows to one of two possible injection points. A hand operated diverter valve in each conveying line allows the carbon flow to be directed to either the flue gas ducts upstream of the SDA pre-cyclone sections or to the SDA vessels after the precyclone. Because of the need to fit the system into the existing facility, field routing resulted in discharge piping distances of between approximately 530' to 580', depending upon the destination chosen. In either case the flow is divided between the pair of ducts entering the two SDAs or between the individual SDAs by ceramic backed wyes. These two locations were chosen to allow a determination of the best injection point relative to carbon consumption. Preliminary tests indicated that adding carbon in the duct upstream of the SDAs was more efficient. It is believed that the longer residence time of the carbon within the flue gas stream resulting from using this location was the reason for this result. Once delivered to the flue gas stream, the powdered carbon adsorbs various volatile forms of mercury including mercuric chloride and elemental mercury present within the gas stream. The carbon is then collected before discharge from the stack by the ESP and is removed with the other flyash.

The carbon used within this system is DARCO FGD, supplied by Norit Americas Inc. It is a lignite coal based activated carbon manufactured specifically for the removal of heavy metals and other contaminants typically found in incinerator flue gas emission streams. According to Norit, it has been proven to be highly effective for the removal of gaseous mercury, dioxins, and furans in numerous full scale operating facilities. Its open pore structure and fine grind permits rapid adsorption, which is critical in this application.

SYSTEM STARTUP

The system installation was completed in December, 1996. Construction was completed under a tight schedule and incurred some delays due to the installation of mercury control systems at the other New Jersey facilities and due to a few site specific issues. Initial startup problems were limited to a few pipe leaks which were quickly fixed.

During initial operation a plug of carbon feed was not maintained in the feed hopper. When this plug is not maintained, the eductor tends to draw the carbon from the silo directly resulting in very high feed rates. It was also found that the eductor vent line cap was too small. This caused the vacuum on the system to be higher than desired compounding the carbon feed rate problem. The vent cap was enlarged correcting the problem. Several other minor modifications were made to upgrade the system for the facility.

In the design of this system, Ref-Fuel adopted an approach relative to the handling of carbon that was deemed to be very conservative. Carbon was considered to be a flammable and explosive material. Dusting, which could lead to an explosion via various means of ignition, was the primary concern where carbon was present as a pure compound and was not diluted with either water or fly ash. As a result, the design included features such as explosion vents on the storage silo in accordance with the National Fire Protection Association Standard 68 (NFPA-68). In addition, all motors and associated electrical equipment, where dry activated carbon was to be handled, was specified to conform to the Electrical Code for Wiring and Motors Exposed to Carbonaceous Dusts (i.e. National Electrical Code, Class II, Division 2, Group F). Once again, this approach was considered to be overly conservative by the system supplier, who has extensive experience with carbon handling.

SYSTEM OPTIMIZATION

It was required by the NJDEP to determine the optimal carbon injection rate for the facility. A test program was constructed to collect data at a baseline condition, as well as three various setpoints centered around the manufacturer's expected setpoint of 20 pounds per hour. Norit determined this value based upon the Essex County historical mercury emission rates. On one unit, three 2-hour runs of USEPA Method 29 were performed at each of the following conditions:

- Baseline Condition (No carbon injection)
- Low Injection Rate (15 pounds per hour)
- Mid Injection Rate (30 pounds per hour)
- High Injection Rate (45 pounds per hour)

To ensure that these injection levels were being achieved, a calibration check of the carbon feed system was performed prior to each group of runs at each setpoint to determine the actual injection rates. For the test program, injection rates of 14.5, 31, and 40 pounds per hour were achieved. Table 1 presents the data from this program.

To determine what the optimal injection rate was, the outlet concentrations of each carbon injection level were plotted, and the equation and slope of the trendline determined. This curve is included as Figure 5. Since the slope of the curve represents the change in mercury emission per unit of carbon used when no significant decrease in mercury emissions was gained when additional increments of carbon were added, this injection rate was determined to be the optimal setpoint. This calculation showed the optimal point to be about 21 pounds per hour. Since this agreed very well with the Norit Americas expected operating setpoint in their system proposal of 20 pounds per hour, the facility selected 21.5 pounds per hour as the operational setpoint.

ONGOING TESTING

Since the New Jersey regulations require quarterly testing for two years, with a provision to go annual thereafter should all results be in compliance, the ECRRF has been conducting inlet and outlet testing since January of 1996. These results are provided as Table 2. The facility, at the predetermined optimal injection rate of 21.5 pounds an hour, has been able to achieve compliance with the current regulation, as well as tentatively demonstrating the ability to achieve compliance with the January 1, 2000 standard. Limited dioxin emission testing has also been completed since the activated carbon system has been in operation. Test results were very favorable as presented in Table 3. The table also shows that particulate emissions were reasonable.

CONCLUSION

The mercury control system has performed very well since startup. Emission control is consistently within permit requirements and the system has been able to demonstrate the design performance objectives. Concerns of meeting the emission requirements for an ESP-equipped facility have not materialized and in fact, the additional dioxin control provided by the system is an extra bonus.

REFERENCES

1. Cooper, L. A.; *Battery Survey for Essex County, NJ*; Proceedings of 1993 Air and Waste Management Association, Municipal Waste Combustion Conference, Williamsburg, Virginia, VIP-32.

2. Suchan, M.; *Mercury Reduction Program for the Essex County Resource Recovery Facility;* Proceedings of the 1995 Air and Waste Management Association, Solid Waste Management: Thermal Treatment and Waste-to-Energy Technologies Conference; Washington, D.C., VIP-53.

Table 1. Essex County Mercury System Optimization Data.

Carbon Injection Setpoint (lb/hr)	Carbon Injection Actual (lb/hr)	Inlet Mercury Concentration (ug/dscm@7%O2)	Outlet Mercury Concentration (ug/dscm@7%O2)	Percent Removal (%)	Average Mercury Concentration (ug/dscm@7%O2)	Average Mercury Removal (%)
0	0		292	N/A		
0	0		176.6	N/A		
0	0		269.2	N/A	245.9	N/A
15	14.5	274.6	64.0	77%		
15	14.5	222.0	33.1	85%		
15	14.5	261.1	65.8	75%	54.3	81%
30	31	174.3	11.0	94%		
30	31	213.4	12.8	94%		
30	31	168.0	13.6	92%	12.5	93%
45	40	245.7	11.4	95%		
45	40	237.8	12.7	95%		
45	40	125.7	13.8	89%	12.6	93%

Table 2. Essex County Quarterly Mercury Emission Data for 1996.

	Boiler 1			Boiler 2			Boiler 3		
Quarter	Boiler Exit (ug/dscm@7%)	ESP Exit (ug/dscm@7%)	Removal (%)	Boiler Exit (ug/dscm@7%)	ESP Exit (ug/dscm@7%)	Remo val (%)	Boiler Exit (ug/dscm@7%)	ESP Exit (ug/dscm@7%)	Removal (%)
1st	135.0	21.5	84%	140.0	20.4	85%	130.0	22.2	83%
2nd	173.0	42.4	75%	151.0	17.0	89%	156.0	35.0	78%
3rd	124.0	27.3	78%	124.0	25.2	80%	140.0	32.1	77%
4th	116.0	16.0	86%	180.0	25.0	86%	109.0	18.0	83%
Average	137.0	26.8	81%	148.8	21.9	85%	133.8	26.8	80%

Table 3. Essex County Dioxin Emission Data with Mercury Control System Retrofit.

Parameter	Facility Average Corrected to 7% O_2 Unit 1	Unit 2	Unit 3
Total Dioxins①, ng/dscm	3.0	1.5	2.0
Particulate	0.0025	0.0010	0.0010

① Total dioxins is inclusive of tetra-octa polychlorinated dibenzo-p-dioxins and tetraocta polychlorinated dibenzo furans reported on a total

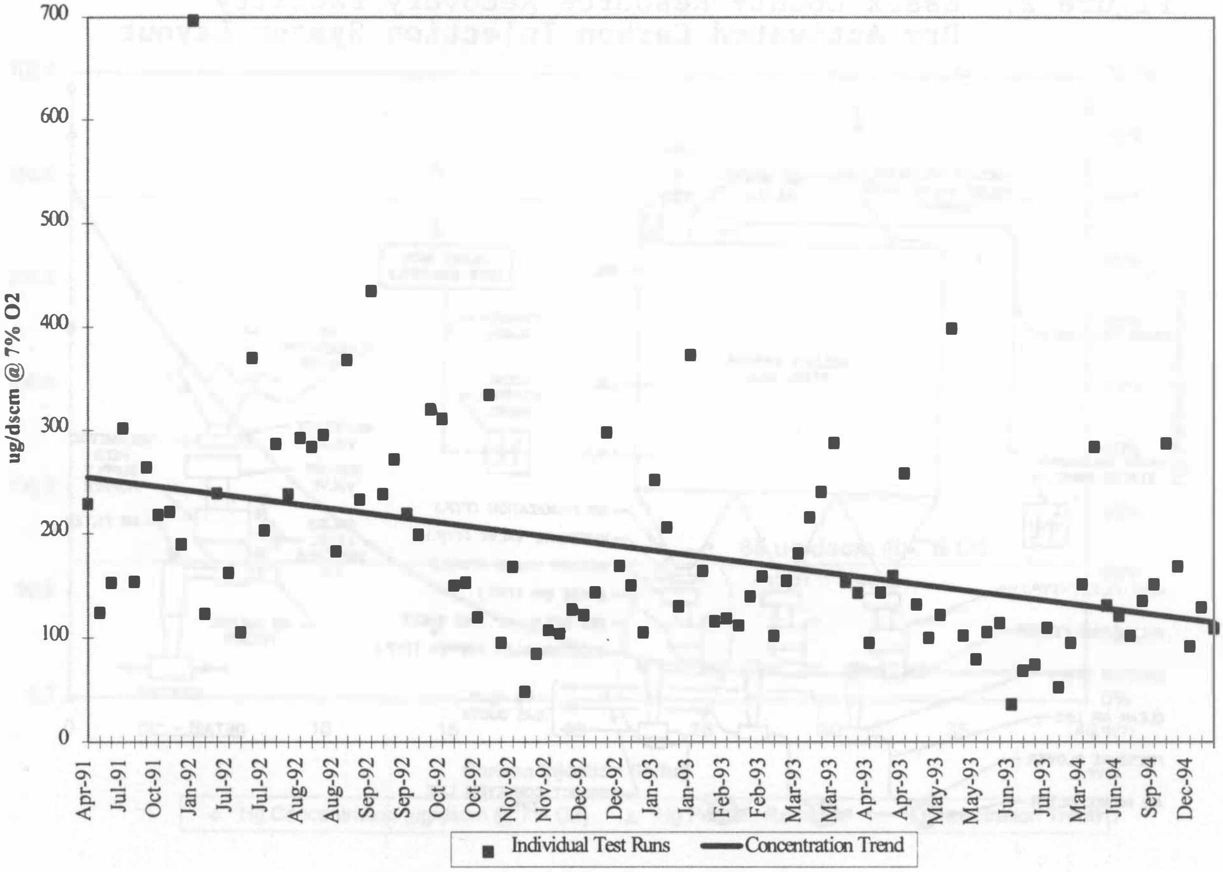

Figure 1. Essex County historical mercury concentrations.

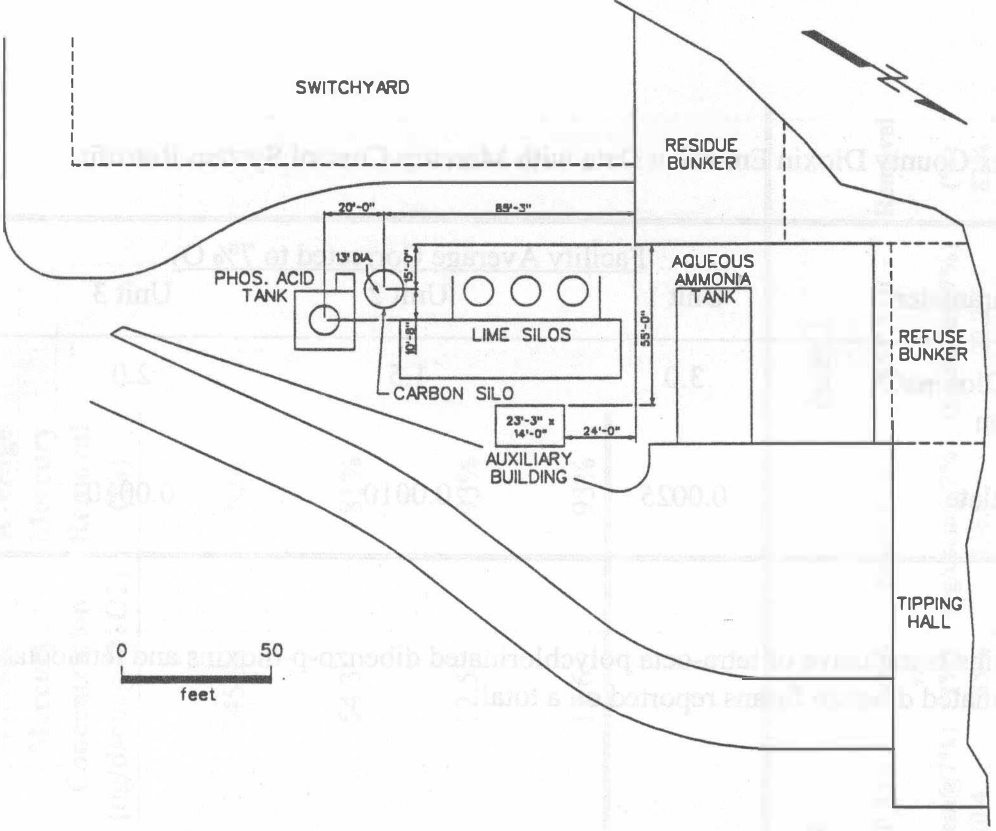

Figure 2. Essex County Resource Recovery Facility Dry Activated Carbon Injection System Layout

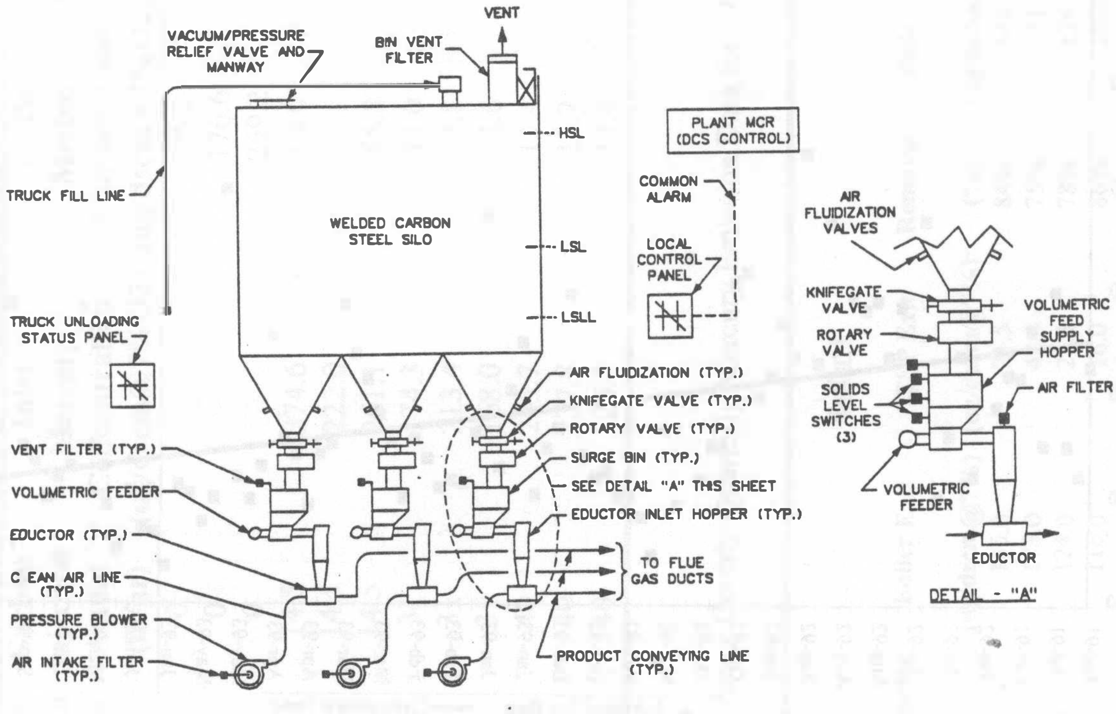

Figure 3. Essex County Resource Recovery Facility Dry Activated Carbon Injection System Simplified Process Floor Diagram

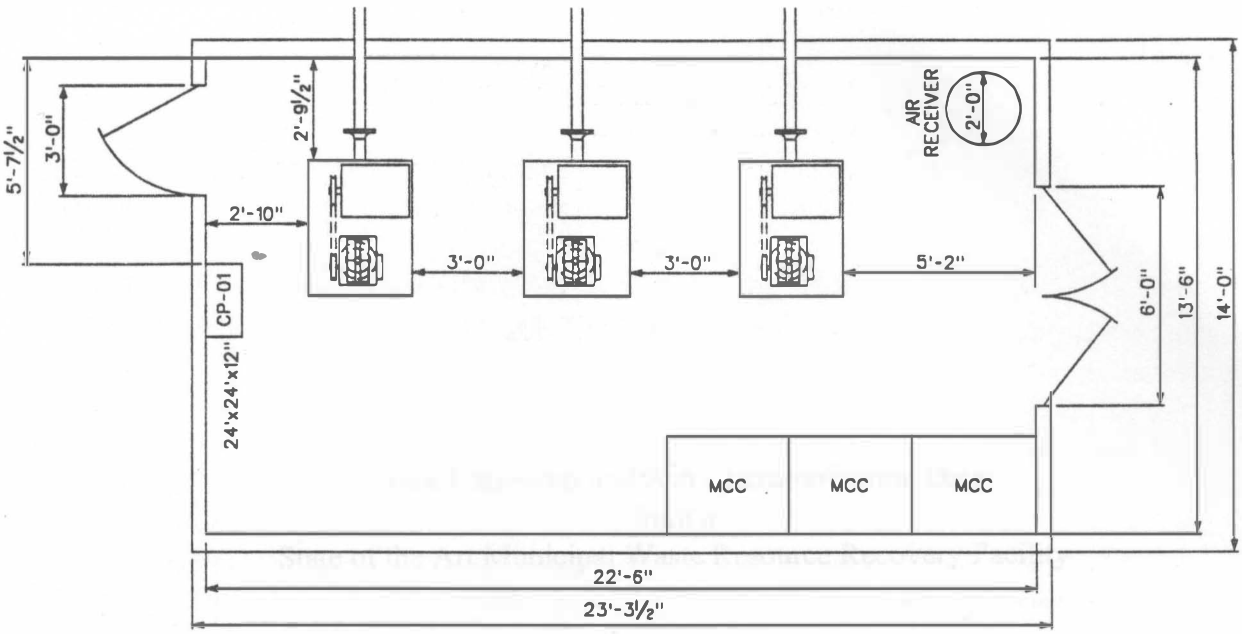

Figure 4. Essex County Resource Recovery Facility Dry Activated Carbon Injection System Auxiliary Building Layout.

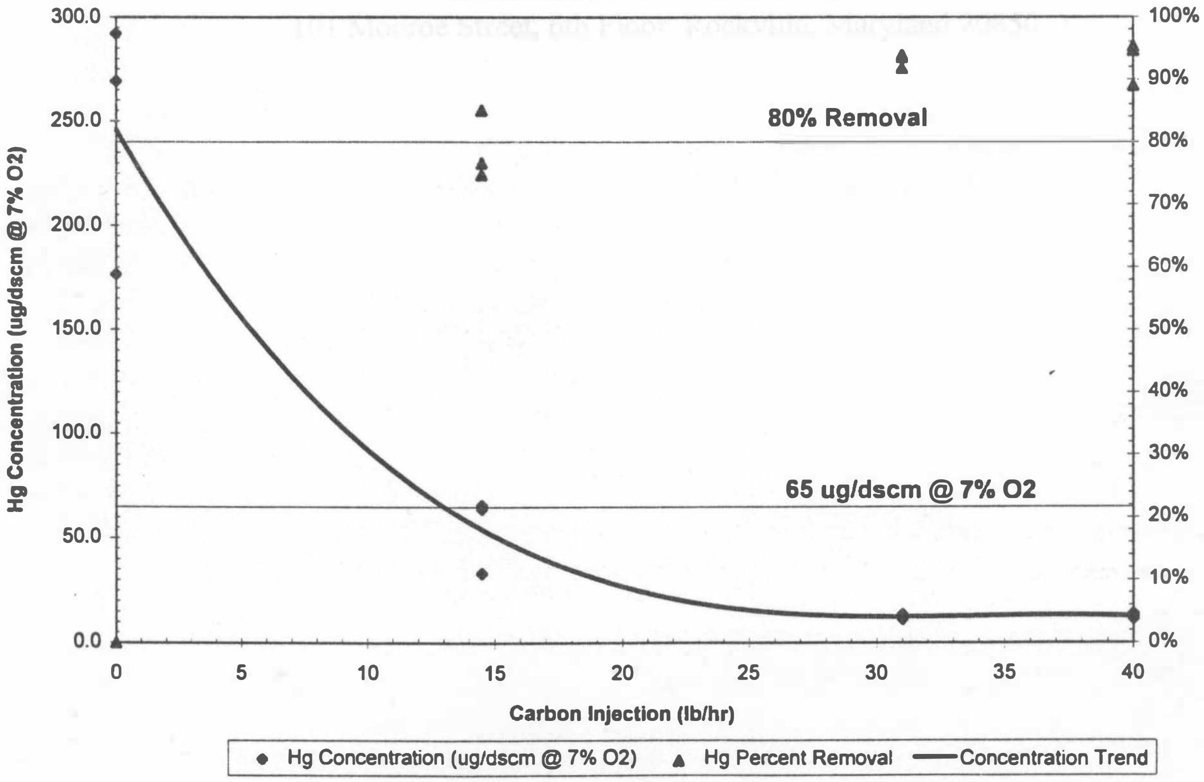

Figure 5. Essex County Resource Recovery Facility Mercury Control Optimization Curve.