AIR POLLUTION CONTROL SYSTEM PERFORMANCE FOR THE COMMERCE REFUSE TO ENERGY FACILITY

EDWIN WHELESS AND MICHAEL SELNA
County Sanitation Districts
of Los Angeles County
Los Angeles, California

ABSTRACT

The Commerce Refuse to Energy Facility consists of a nominal 380 TPD (342 tpd) mass-fired, water wall boiler which has been in operation since December, 1986. The air pollution control equipment for the facility includes Thermal $DeNO_x$ for NO_x control plus a spray dryer and fabric filter for particulate and acid gas removal. A description of the air pollution control equipment is provided with a discussion of the results of an extensive test program conducted as part of the requirements for a Permit to Operate from the local Air Quality Management District.

INTRODUCTION

The quantity of solid waste generated within Los Angeles County presently exceeds 46,000 TPD of which 98% is landfilled. With existing landfills reaching capacity and increasing difficulties in siting new landfills, a solid waste management plan has been developed which would reduce the dependence on landfills through recycling and the combustion of refuse to generate usable energy. A first step in developing this more balanced approach to refuse disposal in Los Angeles County is the Commerce Refuse to Energy Facility which began commercial operation in the Spring of 1987.

A primary consideration in the development of the Commerce Facility was identifying an emission control system consistent with the regulatory requirements for the Best Available Control Technology (BACT). The resultant design represents an integrated approach to minimize plant emissions through the use of combustion controls plus pollution control equipment to reduce the emissions of NO_x, acid gases, and particulates.

This paper presents a description of the Commerce Refuse to Energy Facility and emission control equipment and a discussion of the equipment performance as determined by an extensive test program undertaken to verify compliance with the air permit.

FACILITY DESCRIPTION

The facility is owned by the Commerce Refuse to Energy Authority, a California joint powers authority created pursuant to the Commerce Refuse to Energy Joint Powers Agreement between the City of Commerce (City) and the County Sanitation Districts of Los Angeles County (Districts). Under the terms of the joint powers agreement, the City will direct sufficient refuse from within the City to be delivered to the facility to operate at design capacity and the Districts are responsible for operating the facility. The revenues required to cover debt service and operating costs are derived from the sale of electrical power to the local utility and tipping fees which are equivalent to the cost of the alternative method of disposal (landfill tipping fee plus transportation costs to the nearest landfill).

The facility is a conventional mass burn process which combusts from 320–380 TPD (288–342 tpd) of refuse. The City of Commerce has a large commercial base and a limited residential population. Less than 5% of the refuse generated in Commerce is of residential origin. This produces a refuse with an average heating value of 5000–6000 Btu/lb (11,600–14,000 kJ/kg).

The combustion occurs on a reciprocating grate system provided by Detroit Stoker consisting of a ram feeder and three grate sections. The boiler output is 115,000 lb/hr (52,000 kg/h) of superheated steam at 750°F/650 psig (400°C/45 atm). Design features to minimize high temperature superheater corrosion include a superheater approach temperature which is limited to 1250°F (675°C) plus the use of mechanical rappers, for superheater cleaning.

The superheated steam is used in a turbine to produce 11,400 kW gross, 10,050 kW net electrical power output. The turbine is a full condensing type with two stages of feedwater heating plus a deaerator. Cooling water is provided by a three cell cross flow cooling system.

EMISSION CONTROLS

The emission control strategy employed for the Commerce Refuse to Energy Facility involves a two step process of first minimizing emissions through combustion controls followed by pollution control equipment to reduce the emissions formed.

The first step involves the optimization of the combustion process to insure, to the extent possible, complete combustion. This is achieved through the coordinated design of the under and over fire combustion air system plus plant combustion controls to provide the time, temperature, and turbulence necessary to complete the combustion process.

To reduce the resultant emissions, the Best Available Control Technology (BACT) was employed. This system, as shown in Fig. 1, includes the Thermal $DeNO_x$ system for NO_x reduction and a spray dryer/fabric filter for the reduction of particulate and acid gases.

Combustion Controls

The combustion air is drawn from the refuse storage building and supplied to the boiler by separate over and under fire air fans. The fans were selected to provide a wide range of operational flexibility with the primary air fan capable of delivering up to 100% of the total air required and the over fire air fan capable of providing 60% of the combustion air requirements.

The refuse is loaded into a feed chute and fed onto the grates by a ram feeder. The Detroit Stoker grates consist of three grate sections sloped at 12½ deg. with a drop off between the sections to assist in breaking up the refuse for complete and even burning. Each of the three grate sections consists of two side-by-side grate modules with independent hydraulic drive and combustion air plenums.

Manual dampers are provided to adjust the combustion air flow to the right and left half of each of the three grate sections. The first grate section is used as a drying zone, the second for the actual combustion of the refuse, and the third to complete the burning process. A majority of the combustion air is delivered to the center grate section. The primary air is introduced under the grates and enters the boiler through holes in the face of each grate bar as well as between the grate bars.

The over fire system consists of two separate levels of air injection nozzles as shown in Fig. 2. The lower level of nozzles consist of 2-in. diameter nozzles on both sides of the boiler located approximately 7 ft above the grates and eight 2-in. diameter nozzles at the lower front and rear. A shutoff valve is provided for all side nozzles and every other nozzle at the front and rear to distribute the flow.

A second set of nozzles is located approximately 16 ft above the grates on the front and rear walls. These nozzles are 4 in. in diameter spaced 2 ft on center and have shut-off valves on every other nozzle.

The distribution of the air is such that 60% of the over fire air is supplied to the upper front and rear nozzles with increased air at the corners. With the dry, commercial type refuse normally burned at the facility, the over fire air provides 40–50% of the total combustion air requirements. When the refuse has a higher moisture content consistent with residential refuse, the over fire air is reduced to 25–30% of the total air.

A computer based distributed control system is employed to regulate the refuse and combustion air feed rate. The steam flow is maintained constant by increasing the primary air flow on lower than set point steam flow and reducing primary air flow on steam flow above set point. The over fire air is set at a constant value which is dependent on the composition of the refuse being combusted. The combined effect of the plant control system and combustion air arrangement design has proved effective in maintaining consistently

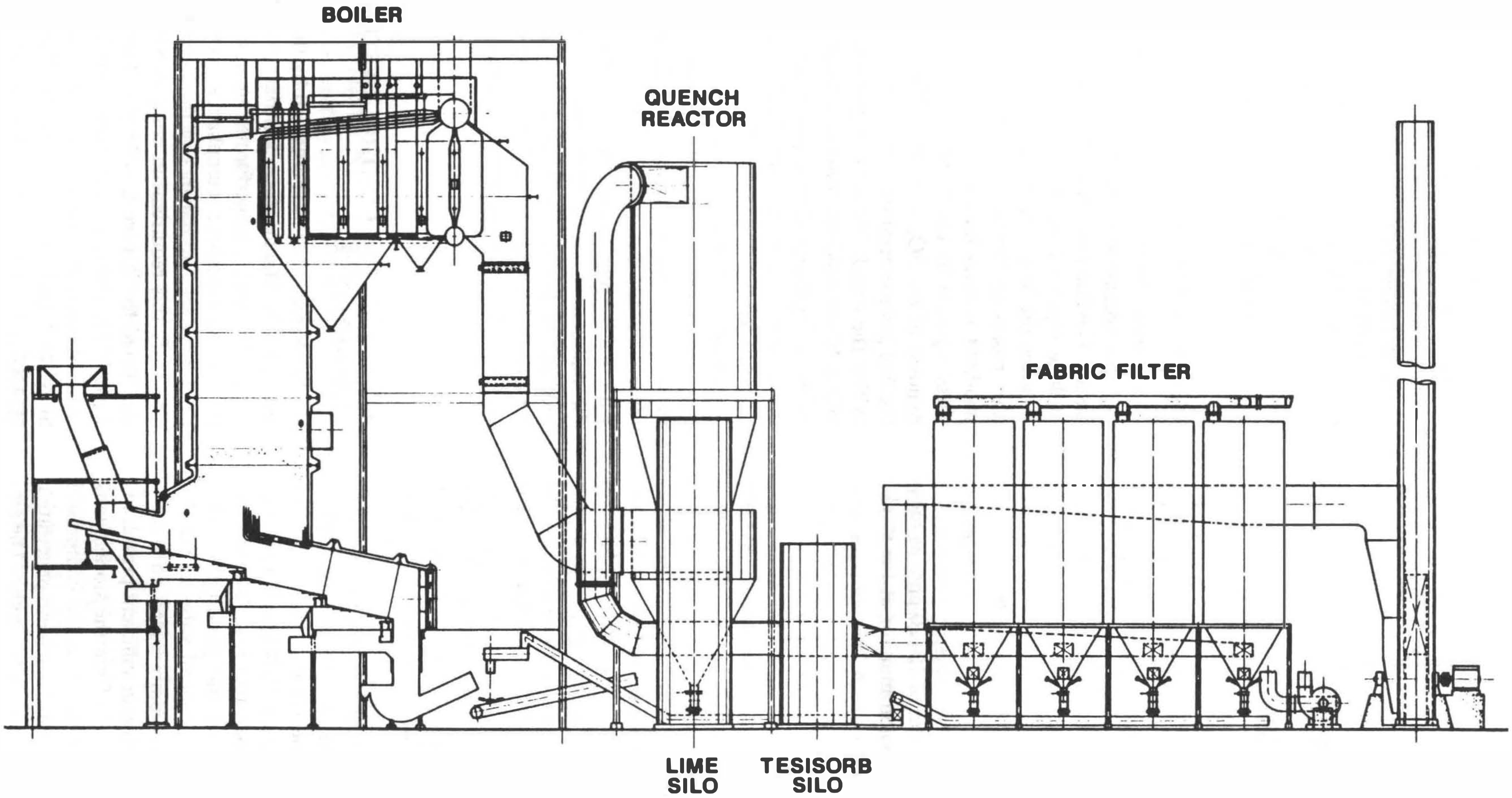

FIG. 1 COMMERCE REFUSE TO ENERGY FACILITY BOILER AND APC EQUIPMENT

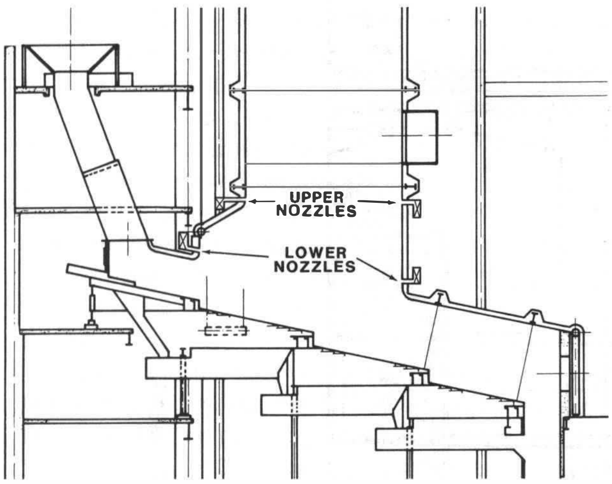

FIG. 2 OVER FIRE AIR SYSTEM

low CO emissions on the order of 10–20 ppm as measured by a continuous emission monitor at the stack.

Thermal DeNO$_x$

Thermal DeNO$_x$ is a selective noncatalytic NO$_x$ reduction process developed by Exxon. The effectiveness of the process is dependent on the chemical reaction between NO$_x$ and NH$_3$ to form nitrogen and water vapor which occurs within a narrow flue gas temperature zone at approximately 1750°F (960°C). NO$_x$ removal in excess of 70% has been predicted by Exxon if there is complete mixing of the ammonia and flue gas at the optimum temperature for the reaction. The process, however is highly dependent on the flue gas temperature at the point of mixing and results in unreacted ammonia at temperatures below the optimum reaction temperature and increased NO$_x$ if the temperature is high.

The Commerce Facility utilizes a system consisting of an ammonia storage tank, air compressor, and injection nozzles on both sides of the boiler. The ammonia is stored as a liquid in a 12,000 gal (45,400 L) pressure vessel. The ammonia vapor is withdrawn from the top of the storage vessel and passed through a pressure regulator and flow control valve to the discharge of a centrifugal air compressor. An electric vaporizer is provided to maintain sufficient pressure in the storage tank. The ammonia from the storage tank is mixed with the compressed air at the compressor exit which acts as a carrier gas to achieve penetration into and mixing of the ammonia in the boiler. The air–NH$_3$ mixture is injected into the boiler through nozzles located on both sides of the boiler which penetrate the furnace wall between the water wall tubes.

Under normal operation the ammonia feed is set at a constant rate. The residual ammonia slip is measured by a continuous emission monitor located at the economizer exit which is used to determine a feed rate consistent with maintaining an ammonia level of less than 40 ppm at the economizer exit.

Spray Dryer/Fabric Filter

The spray dryer is an up flow type reactor which provides primary removal of both particulates and acid gasses. The flue gas from the economizer exit enters a cyclone separator at the base of the reactor which removes the larger particulate fraction. The flue gas then passes up through the reaction zone where five two-fluid nozzles introduce an atomized lime slurry spray upward in the direction of flow for primary removal of the SO$_x$ and HCL. This process reduces the flue gas temperature from 470°F to 270°F prior to exiting the vessel. The spray dryer is designed to provide a 10 sec residence time to complete the reaction. After exiting the spray dryer, a crystalline, hygroscopic dry powder is injected into the flue gas as a conditioning agent for the fabric filter.

The fabric filter is a reverse air type consisting of eight separate modules. Each module contains 156 8-in. diameter, fiber glass bags. The fabric filter is conservatively designed with an air to cloth ratio of 2:1 with one module off line for cleaning and one off line for maintenance. During normal operation with all modules on line the air to cloth ratio of 1.5:1 allows for a thick filter cake to minimize particulate emissions and provide secondary removal of acid gases.

AIR POLLUTION CONTROL SYSTEM PERFORMANCE

The Permit to Construct issued by the South Coast Air Quality Management District (SCAQMD) requires that testing be performed upon facility completion to demonstrate compliance with the permit conditions prior to issuance of the Permit to Operate. To satisfy this requirement, comprehensive tests were conducted the last week of May and the first week of June, 1987. The tests were performed by Energy Systems Associates (ESA) in the presence of the SCAQMD and the California Air Resources Board (CARB). The test program was expanded to include

TABLE 1 SUMMARY OF EMISSION RESULTS
COMMERCE REFUSE-TO-ENERGY FACILITY

Species	Emission Rate	SCAQMD Permit Condition
NO_x: ppm at 3% O_2	116	186
SO_x: ppm at 3% O_2	1.7	29.
CO: ppm at 3% O_2	20	134
HC by CARB 1-100+: ppm at 3% O_2	<1	
HC by TCA/[illegible] ppm at 3% O_2	33	
Total Particulate: gr/dscf at 12% CO_2	0.0043	.016
HCl: ppm at 3% O_2	11.4	
HF: ppm at 3% O_2	0.049	
Total chlorinated HC*, ppb	<3	
Chlorobenzene	<0.1	
Chlorophenol	<30	
Total PCDD, ng/m^3**	0.61	
Total PCDF, ng/m^3	1.20	
Total PCDD/PCDF, ng/m^3	1.81	

*Except chlorobenzene and Chlorophenol
**Corrected to normal conditions of 0°C, 14.7 psia, 12% CO_2
+Data by CARB

the criteria pollutants plus dioxins, furans, and heavy metals.

All the testing, with the exception of the last day, was performed with the boiler at full load on normal refuse from the City of Commerce. The tests on the final day for dioxin and furan were conducted with residential refuse from a neighboring city, to provide an indication of system performance on a more typical refuse.

A summary of the test results is presented in Table 1. A discussion of the test results follows.

NO_x Emissions

The emission tests for NO_x included three tests of 1-hr each with a constant ammonia feed rate followed by a 1-hr test without ammonia injection. The ammonia feed was then increased for a final test. The results of these tests are presented in Table 2. The stochimetric feed ratio of the ammonia and NO_x removal efficiency are based on the uncontrolled NO_x measured without ammonia feed.

The optimum performance of the Thermal $DeNO_x$ system has yet to be established. Upon certification of the facility continuous emission monitors (CEM), a comprehensive test program will be conducted to establish the uncontrolled NO_x emissions for various

TABLE 2 NO_x EMMISSION TEST RESULTS

	NH_3/NO_x	NO_x ppm	NO_x ppm_{vd} @3% O_2	%NO_x Removal
Tests With NH_3	1.45	68	120	
	1.45	64	112	
	1.45	69	118	
Average	1.45	67	116	42
Without NH_3	0	121	199	
High NH_3 Feed	2.0	48	80	60

combinations of excess O_2 and over fire/under fire air configurations and the optimum injection location and NH_3 feed to maximize the NO_x removal. This test program is scheduled for late 1987.

In general, the Thermal $DeNO_x$ system appears to provide NO_x removals which are consistently in the range of 30–40% with the capability of achieving 60% as demonstrated during the compliance testing.

The major potential concerns with the injection of ammonia, formation of an ammonium chloride plume and ammonium bisulfate economizer fouling, have not been experienced. At this point, after 6 months of operation, it appears that an ammonium chloride plume is not a matter of concern if applied to a boiler with a spray dryer and fabric filter.

Ammonium bisulfate economizer fouling has been experienced in other $DeNO_x$ applications but was not expected with the concentrations and temperatures associated with refuse firing. To date, this potential problem has not been observed.

CO Emissions

CO emission tests which were conducted concurrently with the NO_x tests produced the following results:

Test	CO Emissions ppm_{vd}	CO Emissions ppm_{vd} @ 3% O_2
A	12	21
B	12	21
C	11	18
Average	12	20

These results, obtained with the boiler operating at full load, demonstrate the effectiveness of the over and under fire air system in achieving complete combustion. During these tests the ratio of over to under fire air was 45/55, respectively, which is normal for the relatively dry commercial waste combusted at the fa-

TABLE 3 EMMISSION DATA FOR SO_x, HCL, HF AND NH_3

	Average ppm at 3% O_2, Dry								
Location	Boiler Exit			Stack				Removal, %
Test No.	A	B	Ave.	C	D	E	Ave.	
SO_2	405	194	300	1.49	1.29	1.89	1.56	
SO_3	57	47	52	.18	.15	.11	.15	
SO_x	462	241	352	1.67	1.44	2.00	1.70	99.5
Test No.	F	G	Ave.	H	I	Ave.		
HCl	1,389	914	1,152	14.3	8.4	11.35		98.8
HF	19	21	20	.051	.046	.049		99.7

TABLE 4 AVERAGE SO_2 AND HCL

	Spray Dryer Inlet	Spray Dryer Outlet	Stack
SO_2:			
ppm	73	30	2.8
ppm at 3% O_2	116	48	4.4
Removal efficiency, %	---	60.8	96.4
HCl:			
ppm	653	129	2.9
ppm at 3% O_2	940	179	4.2
Removal efficiency, % (lb/hr)	---	80.9	99.6
Gas Temperature, °F	489	259	255
Moisture, % by volume	11.9	18.9	19.0
Gas Flow, wacfm	125,600	97,600	92,600
Gas flow, dscfm at 60 °F	60,100	56,900	54,800

cility. During periods when the refuse has a higher moisture content the amount of under fire air is increased.

SO_x, HCL and HF Emissions

The emission test results for SO_x, HCl and HF are presented in Table 3 for the boiler exit and the stack. Since the boiler exit and stack testing was not conducted simultaneously the removal efficiency presented is only for general reference.

The tests were conducted with a fabric filter inlet temperature of 270°F and a lime stochimetric ratio of approximately 1.7:1 based on the average SO_x and HCl concentration measured at the boiler exit.

Prior to the compliance tests, tests were conducted by ESA to determine SO_2 and HCl concentration at the spray dryer inlet, outlet, and stack. The results presented in Table 4 demonstrate the importance of the fabric filter in achieving the high overall removal efficiencies.

TABLE 5 PARTICULATE MEASUREMENTS (gr/DSCF at 12% CO_2)

	Boiler Exit	Spray Dryer Exit	Stack
Solid	1.78	2.64	.0029
Condensible	.23	--	.0014
TOTAL	2.01	2.64	.0043

Particulate

The particulates were measured at the spray dryer outlet and stack using EPA Method 5 with analysis for the condensable fraction. EPA Method 17 "In-Stack Filtration" was used at the boiler exit due to the high grain loading and sample port configuration. The results are presented in Table 5.

These results are based on the average of two tests at the boiler and spray dryer exit and the average of three tests at the stack. All tests were conducted with the ammonia injection system operating and all eight fabric filter modules in operation.

PCDD/PCDF

The PCDD/PCDF measurements presented in Table 6 were collected according to the draft CARB Modified Method 5 (semi-VOST) method. Tetra- through octa- PCDDs and PCDFs were measured in-

TABLE 6 PCDD/PCDF EMMISSIONS FROM COMMERCE REFUSE-TO-ENERGY FACILITY

Location	Concentration, ng/Nm^3 @ 12% CO_2				
	Boiler Exhaust	Stack			
Test	17	15	16	17	Avg
2378-TCDD	ND<0.097*C	ND<0.003*C	ND<0.003*C	ND<0.003*C	ND<0.003
Total TCDD	0.865	0.033	0.032	0.27	0.112
12378-PCDD	0.097	ND<0.002	ND<0.001	ND<0.005*	ND<0.003
Total PCDD	0.448	0.011	0.011	0.130	0.051
123478-HxCDD	0.078	ND<0.003*	ND<0.001	0.005	<0.003
123678-HxCDD	0.124	ND<0.008*	ND<0.006*	ND<0.017*	ND<0.011
123789-HxCDD	0.124	ND<0.008*	ND<0.010*	0.015	<0.011
Total HxCDD	1.261	0.055	0.056	0.195	0.102
1234678-HpCDD	1.067	ND<0.058*	0.059	0.127	<0.081
Total HpCDD	2.16	0.062	0.059	0.254	0.125
OCDD	0.47	0.153	0.213	0.31	0.225
Total PCDD$^+$	8.20	0.314	0.370	1.15	0.611
2378-TCDF	0.59C	ND<0.020*C	ND<0.024*C	ND<0.041*C	ND<0.028
Total TCDF	11.5	0.227	0.51	1.56	0.77
12378-PCDF	0.78	ND<0.003*	0.003	0.012	<0.006
23478-PCDF	0.51	ND<0.015*	ND<0.016*	0.051	<0.027
Total PCDF	2.83	0.059**	0.057	0.27	0.129
123478-HxCDF	0.64	0.03	0.016	0.056	0.034
123678-HxCDF	0.37	ND<0.012*	0.011	0.029	<0.052
234678-HxCDF	0.03	0.015	0.011	0.032	0.019
123789-HxCDF	ND<0.0006	ND<0.001	ND<0.001	ND<0.0005	ND<0.001
Total HxCDF	2.91	0.077	0.089	0.24	0.135
1234678-HpCDF	ND<0.0006	ND<0.001	ND<0.001	0.159	<0.054
1234789-HpCDF	0.156	ND<0.001	ND<0.0011	ND<0.008*	ND<0.003
Total HpCDF	2.18	0.086	0.075	0.22	0.127
OCDF	0.88	ND<0.032*	ND<0.041*	0.071	<0.048
Total PCDF$^+$	20.3	0.480	0.771	2.36	1.20
Total PCDD/PCDF	28.5	0.794	1.14	3.51	1.82
Surrogate Recovery:					
13C12-TCDF	98.3%	97.7	104.0	92.8	98.1
37Cl-TCDD	94.0%	101.1	103.2	95.3	99.9
13C12-HxCDF	90.4%	86.9	91.2	85.4	87.8

* - EMPC (estimated maximum possible concentration; see Section 3.3.7)

** - Ether interference

C - Confirmation result

\+ - Sum of total values for Cl_4 thru Cl_8 subtotals, ND values are included in totals

TABLE 7 2,3,7,8 TCDD TOXIC EQUIVALENT EMISSIONS
(ng/N_m^3 at 12% CO_2)

	Total PCDD/PCDF	California DOHS Measured	California DOHS Detection Limit	Swedish Measured	Swedish Detection Limit	EPA Measured	EPA Detection Limit
Commerce Refuse							
Stack, Test 15	.79	.001	.047	.0005	.018	.0012	.009
Stack, Test 16	1.14	.007	.051	.0014	.019	.0018	.010
Avg.	.97	.004	.049	.001	.019	.0015	.010
Residential Refuse							
Boiler Exit	28.5	2.05	2.15	.738	.835	.287	.381
Stack	3.5	.076	.125	.023	.045	.014	.024
Reduction %	88	96	94	97	95	95	94

NOTE: For columns labeled "Detection Limit", the values reported are based on using the respective detection limits where the species were not detected. For columns labeled "Measured" the actual Quantities detected were used to compute the toxic equivalent with a value of zero used for quantities below the detection limit.

cluding all 2, 3, 7, 8 isomers. In this procedure a sample is collected isokinetically and passed through a heated quartz Method 5 filter followed by an XAD-2 sorbent module in a water-cooled jacket. The sorbent module is followed by an impinger train to collect moisture and any dioxins and furans that might pass through the resin.

For the dioxin results, two types of detection limits are presented for species where no measurable quantities were present. "DL," or detection limit, is the limit of detection for samples presenting an analyte response that is less than 2.5 times the background level. "EMPC", representing the estimated maximum possible concentration (amount per sample), is reported for CG/MS signals eluting within the PCDD/PCDF retention time windows established with the daily GC performance analysis, and which are characterized by a signal-to-noise ratio in excess of 2.5:1 but do not meet all the qualitative identification criteria for the species of concern.

Two tests, labeled 15 and 16, were conducted at the stack burning the largely commercial waste normally received at the Facility. A third test (Test 17) was conducted with simultaneous measurement at the boiler exit and stack while burning residential refuse brought in from a neighboring community specifically for this test run.

The 2, 3, 7, 8-TCDD toxic equivalent is presented in Table 7 using the California DOHS-Method IV, the EPA and the Swedish method. The results are presented based on the actual levels measured and also for the detection level. For columns labeled "detection limit," the values reported are based on using the respective detection limits where the species were not detected. For columns labeled "measured" the actual quantities detected were used to compute the toxic equivalent with a value of zero used for quantities below the detection limit.

As a basis of comparison, the three test average 2, 3, 7, 8 toxic equivalent by the Swedish Method of 0.027 ng/NM^3 at 12% CO_2 for Commerce relates to a reported value of 0.155 for Marion County and 0.808 for Wurzburg.

As evident from Table 7, however, reported values for toxic equivalents for modern plants may be more a function of detection limits than actual emissions.

CONCLUSIONS

Implementation of refuse to energy facilities in California and many other areas will require the successful application of the Best Available Control Technology (BACT). As evident by the compliance test results for the Commerce Facility, very low emission levels are achievable for both the criteria pollutants and dioxins.