

UPGRADING EXISTING MWCS WITH ESPS: THE CONTRIBUTIONS OF COMBUSTION IMPROVEMENT VERSUS APC TEMPERATURE REDUCTION

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ABSTRACT

Existing municipal waste combustors (MWCs) will have to comply with more stringent stack emissions limits as the recently published guidelines come into effect, and the States respond with the same or stricter regulations. Those with state-of-the-art emissions controls, such as scrubber/baghouses, may have to reduce dioxin and mercury emissions further. Existing facilities lacking acid gas controls will have to add them, and also meet stringent dioxin and metals emissions limits. Many remedies are available, including improving combustion efficiency by providing computer control and improved methods of supplying combustion air, reduction of emission control device temperature, and injection of alkaline reagents and activated carbon. This paper investigates the contributions of both improved combustion and reduction in emission control temperature in reducing dioxin emissions to EPA guideline limits. The potential use of real-time surrogates for dioxins, including not only CO but chlorobenzenes, for diagnostic testing and monitoring of performance, is discussed.

INTRODUCTION

The technologies employed by municipal waste combustors (MWCs) have evolved from trash heap combustion to modern computer-controlled systems having reciprocating stokers, highly effective computer-control of combustion air, highly effective emission controls, and continuous flue gas analysis, control and monitoring devices. This evolution has progressed under pressure from the public and regulators, and the desire of vendors to offer more effective equipment and facility operation.

Emissions guidelines for existing MWCs

The Final Draft Emission Guidelines for existing facilities, published by the U.S. Environmental Protection Agency (EPA) in October, 1995 are shown in Table 1. These will severely affect

MWCs which employ electrostatic precipitators (ESPs) and are not presently equipped with acid gas controls. The affected facilities include six large waste-to-energy facilities containing 16 MWC lines and an additional 19 small plants consisting of 38 combustion lines. These facilities represent about 22,000 tons per day (TPD) of municipal solid waste (MSW) disposal capacity.

Most of the MWCs which have been built in the last ten years have been equipped with dry- injection or spray-dry scrubbers with ESPs or baghouses, which are classed as Best Available Control Technology (BACT). Retrofitting the older MWCs which do not have acid gas controls with these technologies could easily cost \$15,000 per ton of acid gas removed, compared with the EPA cost effectiveness guideline of \$2,000 per ton removed, and could add \$20 per ton to the cost of MSW combusted. In view of present costs of waste disposal, this penalty could make the facility economically uncompetitive, resulting in its abandonment, while the community would be obliged to continue to pay off the bonds which financed the facility.

More efficient ESPs and fabric filters have succeeded in reducing particulate matter emissions from early regulatory levels of 0.08 grains per dry standard cubic foot (gr/dscf), corrected to 7% oxygen, to under 0.010 gr/dscf, hence this has become the new federal standard for new sources (NSPS). This limit allows some leeway for normal variations in emissions from test to test. The new emission guidelines (EGs) for existing facilities require that 0.030 gr/dscf for small plants and 0.012 gr/dscf for large plants, as seen in Table 1. Acid gas controls for existing facilities will have to meet sulfur dioxide (SO₂) limits of 80 ppm or 50% reduction for small facilities, and 31 ppm or 75% reduction for large facilities. For small facilities, HCl must be reduced by 50% or to 250 ppm, and by 95% or to 31 ppm for large facilities. Control of NO_x emissions is not required for small plants and refractory-walled combustors, but

large waterwall plants must meet 200 ppmv, and those with rotary waterwalls or those burning refuse-derived fuel must meet a limit of 250 ppmv. Mercury emissions are limited to 80 ng/dscm for all plants. The limits for cadmium and lead are set according to the plant capacity. Total polychlorinated dibenzodioxins (PCDD) plus polychlorinated dibenzofurans (PCDF) are limited for small facilities to 125 nanograms per dry standard cubic meter (ng/dscm), and for large facilities to 60 ng/dscm for facilities with ESPs, and 30 ng/dscm for those with fabric filters. These limits translate to 2, 1 and 0.5 ng/dscm toxic equivalent (TEQ), respectively, using EPA's conversion factor of 60. For MSW, the international toxic equivalent (ITEQ) can be closely approximated by dividing by fifty: this has been done in this paper when only total PCDD and PCDF data were available. Many of the states have imposed more stringent emission limits. When investing in retrofits, it must be anticipated that existing facilities might in time be required to meet the limits imposed by the EPA for new facilities, including 13 ng/dscm for PCDD+PCDF. These limits have been and can be met by existing, and hence by new, state-of-the-art MWCs equipped with dry alkaline reagent injection and spray-dry scrubbers and ESPs or baghouses, in some cases by applying some kind of activated carbon injection or a product such as Sorbalit. (Licata, 1994)

It must not be overlooked that regulations must be set at high enough levels to allow for the range of variation which is observed during the course of normal operation due to operating variables and variations in the composition of waste at the times during which tests are performed. The highest readings of PM and metals emissions (pollutants which are not directly controlled) are often over three times the average of periodically measured readings. Hence any one test or set of tests might fail to meet the standard, although the long-term average might be well below the standard.

The question is, how can the existing MWCs facilities which do not have acid gas scrubbers be upgraded at costs which will allow them to stay in business? Complete replacement of the ESP with spray-dry scrubbers may not be possible due to space limitations, or at costs which can be afforded by the community or the operator when faced with the costs of landfill.

Available retrofit technologies

Particulate controls. ESPs having three or more fields have been able to meet the particulate (PM) control standards of Table 1, although they may need some modifications. If they have only two or three fields, and are slated for major overhaul, it may be more economical to replace them with baghouses, provided space is available.

SO₂ and HCl control. Acid gas control can be accomplished by adding lime or other alkaline reagents to the MSW feed, in the furnace, or after the boiler and before the ESP. However, reductions in emission control operating temperatures are also primary requirements for reducing emissions of the acid gases, volatile metals and organics such as dioxins. Pakrasi (1993) found that relative humidity (RH) was the controlling factor for HCl removal efficiency.

NITEP (1986) tests performed at a pilot installation processing a slipstream from a conventional mass-burn MWC showed that dry injection of lime, or spray-drying a lime slurry prior to a baghouse

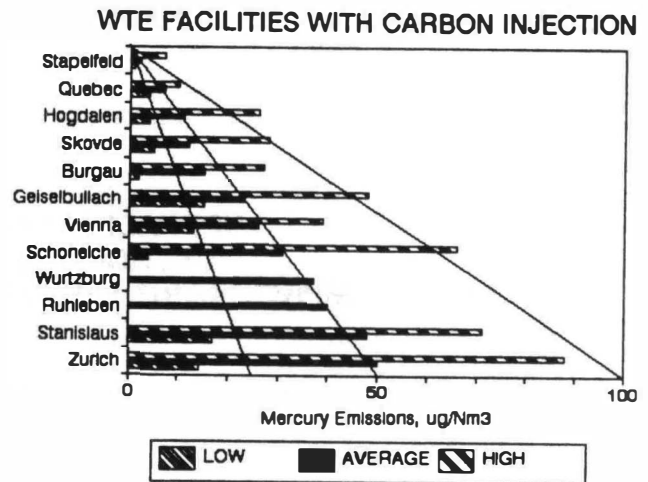


FIG. 1 MERCURY EMISSIONS FROM MWCs EMPLOYING ACTIVATED CARBON INJECTION.

could reduce SO₂, HCl, metals, mercury and PCDD/DF emissions to low levels, especially if the baghouse temperature was reduced to 250°F to 300°F. (NITEP, 1986) These findings resulted in establishment of these technologies as BACT for new facilities. It was found that substantial control was achieved while the dry lime was in suspension, and within the spray-dryer, the remainder being achieved in the baghouse, due to the lengthy retention of the particulate on the bags.

Unfortunately, scrubbers employ vessels with large diameters, from 8-foot to 22-foot, for which there may not be sufficient space. Dry reagent-injection scrubbers with water attenuation may also require additional space which may not be available.

It may be possible to achieve practical and cost-effective upgrading of existing facilities with ESPs by applying site-specific innovative methods for injecting dry reagents and reducing the gas temperatures. The Davis County demonstration is directed to this purpose. (Rigo, 1996)

Control of Metals. Most of the criteria metals, arsenic, lead, cadmium, chromium and nickel, are reduced by over 99% by the devices which remove particulate matter. Tests of spray-dryers followed by ESPs show that in spite of the use of highly efficient ESPs, metals removal performance did not match that of baghouses, at least partly due to shorter retention time. (Hasselriis, 1996) Recirculation of the ESP collection products could be employed, however, to provide additional retention time: this deserves further demonstration and quantification.

Small and large existing plants with ESPs may be able to meet the cadmium and lead stack emissions guidelines if they can meet the PM limits of 0.012 gr/dsf for large plants and 0.030 gr/dscf for small plants. Upgrading of the ESPs may be necessary.

Mercury behaves differently: it can be removed by adsorption, absorption and chemical treatments. (Getz, 1992) Figure 1 shows the mercury emissions measured at twelve facilities, as well as the low, average and high data. (Licata, 1994) (Clarke, 1993) The range of emissions depends not only on the input levels, but also the quantity of reagent used and the target emission standard.

TABLE 1. GUIDELINES FOR EXISTING MWCS, OCTOBER 1995

EMISSIONS	SMALL	LARGE
Capacity:	35-225 Tons/day	>225 Tons/day
SO ₂ *	50% reduction or 80 ppm	75% reduction or 31 ppm
HCl*	50% reduction or 250 ppm	95% reduction or 31 ppm
Particulate*	0.030 gr/dscf	0.012 gr/dscf
Cadmium, mg/dscm	0.10	0.040
Lead, mg/dscm	1.6	0.49
Mercury, mg/dscm	0.080	0.080
PCDD/PCDF* Total mass	125 ng/dscm	60 ng/dscm with ESP 30 ng/dscm with FF
Opacity	10%, 6 minute average	10%, 6 minute average

*Corrected to 7% oxygen.

Activated carbon injection. The use of carbon injection, or injection of a lime/carbon product such as Sorbalit, not only controls mercury, but also dioxins and furans, provided that the gas temperatures have been reduced sufficiently. The reason why these two pollutants of concern are so effectively removed by this single expedient has to do with the adsorption which takes place in the interstices of activated carbon at reduced temperatures. (Licata, 1994)(Getz, 1992). ESPs without acid gas control were typically operated at temperatures from 400°F to 450°F, which are too high for effective mercury and dioxin control. There is little data on the effectiveness of carbon injection when the emission control is an ESP, especially at the reduced APC temperatures which would be expected to reduce mercury emissions. The ASME/NREL tests at Davis County are designed to demonstrate operation at temperatures as low as 300°F. (Rigo, 1996)

Nitrogen oxide control. Control of NO_x to levels at or under 200 parts per million by volume (ppmv), which is required by the USEPA, can be accomplished by a number of means. Refractory-walled MWCs have the advantage that more constant temperatures can be maintained in the furnace (with computer control), such that the desired 1600°F to 1800°F range can be maintained without significant excursions above that upper limit. Waterwall furnaces, when required to maintain 1800°F at the last point of overfire air, usually operate with 2200°F or higher flame temperatures. As a result of these different furnace temperatures, refractory MWCs may be able to keep average NO_x levels close to 200 ppm, whereas waterwall furnaces are more likely to exceed 300 ppm. Active NO_x controls such as ammonia and urea injection, or methane reburning, may be required by waterwall MWCs. Flue gas recirculation, water injection, and other methods may be able to control NO_x emissions of refractory MWCs below the guideline of 200 ppm.

Dioxin and furan control. Many methods are available for

achieving reductions in emissions of dioxins and furans (PCDD/PCDF) to meet the proposed limits for both existing and new facilities. These will be described below.

Acid gas control at facilities with ESPs

As early as 1983 it was demonstrated that depositing hydrated lime upon the MSW as it was fed to a mass-burn MWC was capable of reducing HCl emissions by 50%, or to 150 ppmv. It was also found that PCDD/PCDF were also reduced drastically by this procedure: strangely, this finding did not become widely known. (Boisjoly, 1984)

Tests of dry lime injection in the furnace, and lime and other reagents into the gas stream prior to an ESP or baghouse were carried out at several facilities. Finding that 50 to 80% control could be achieved by routine reagent injection, some facilities have adopted this procedure in normal operation. However, only limited scientific testing has been carried out and reported since the cost to a single facility can generally not be justified. (Beckman, 1989)

Montgomery County (Dayton, OH) has been using furnace injection of limestone for several years, meeting the objective of better than 50% control and emissions of under 50 ppm of SO₂. (Kilgroe, 1991) Limestone is less costly than hydrated lime, but its utilization is less complete. Since the ash residues may contain more alkaline material, the pH of quench water may increase sufficiently to cause the ash to fail the TCLP test for lead.

Davis County (UT) tested both injection of hydrated lime in the furnace and injection of trona, a natural sodium-based reagent, after the boiler, to control both SO₂ and HCl after the facility was started up in 1989, demonstrating that it could meet the requirements of the state at that time. (Beckman, 1989) (Rigo, 1993)

North Andover (MA) recently completed tests of furnace lime injection and duct sorbent injection, demonstrating the effectiveness in controlling SO₂. However, no effect on HCl emissions was achieved, probably due to the high temperature at which the ESP operates. These tests demonstrated that there was no loss of

particulate control by the ESP, but some additional fouling of the boiler was observed. (NREL, 1994) Some vendors have proposed and demonstrated dual-agent injection systems, employing lime for the SO₂ and a sodium bicarbonate reagent for HCl.

Methods for cooling stack gases

While implementation of dry reagent injection is relatively simple, reduction of air pollution control (APC) temperatures is more problematic. Water injection can be applied to cool the gases, but providing sufficient volume to evaporate the water can be difficult.

The ASME Research Committee on Industrial and Municipal Waste, in conjunction with the NREL has carried out a demonstration at Davis to test effective water-spray attemperation in limited duct volume to confirm that, combined with dry reagent injection, the EPA standards for existing MWCs can be met. (Rigo, 1996) Use of heat transfer surface eliminates the problems associated with fouling and deposits in the boiler and ducting, but in order to compensate for the reduction in humidity, somewhat lower temperatures are required to achieve the same acid gas control efficiency. For instance, to obtain the efficiency achieved by spray-dryers or humidification at the usual 275°F to 300°F, all-dry injection systems with dry cooling may have to operate at 250°F to 275°F. Recirculation of flyash and reaction products can be used to compensate for the lack of retention time in ESPs.

DIOXIN CONTROL

Bench tests and research performed with pilot-scale combustors and emission control devices have provided important insights into ways and means of controlling organic, inorganic and acid emissions from combustion of MSW. (Drum, 1994) (Gullett, 1994) Only full-scale demonstration will confirm their applicability, and the levels of control which they can actually achieve in operating MWC facilities.

Graphical representation of emission control progress

Over the last ten years, drastic reductions have been achieved in the emissions of MWCs. Particulate emission reductions from 0.08 to as low as 0.005 gr/dscf have reduced metals emissions by over 99%. Figure 2 shows the range in dioxin (PCDD) and furan (PCDF) emissions reported since the early tests in 1983 to recent tests in 1994. (EPA, 1993) The reductions resulting from combustion control, baghouse control, and carbon injection span orders of magnitude. Over 1000-fold reductions were achieved due to improvements in combustion control, a ten-fold additional reduction resulting from scrubber/baghouse emission controls, and a further ten-fold reduction due to carbon injection. Also shown are data from two 1994 tests at the Montgomery County (Dayton, OH) MWC, showing the effect of reducing the operating temperature of the ESP from 550°F (286°C) down to 392°F (200°C), resulting in a 99% reduction. (Entropy, 1994)

Methods for reducing dioxin emissions at the stack

Data obtained from laboratory and full-scale facility research have provided important insight into the effect on dioxin emissions of good combustion, as well as the gas temperatures in the APC. Analysis of data from tests of MWCs shows that both factors are important. There are many factors which determine the quantities of dioxin precursors which are present in the flue gases and the formation of dioxins and furans by de-novo synthesis on particulate

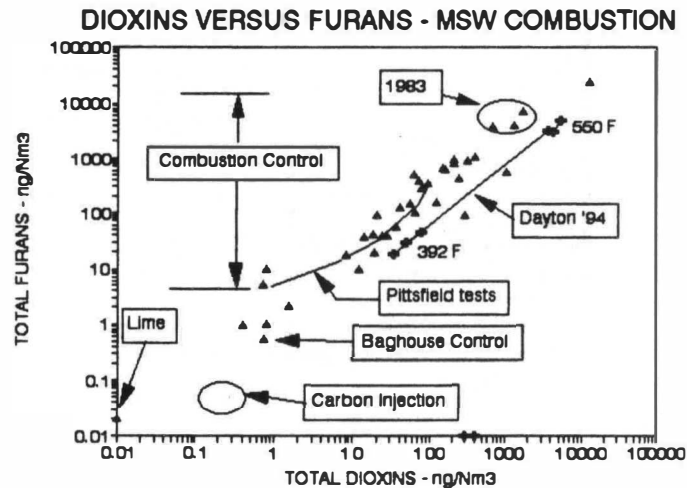


FIG. 2 TOTAL DIOXIN (PCDD) AND FURAN (PCDF) EMISSIONS FROM VARIOUS TESTS OF MWCs, SHOWING THE RANGE OF REDUCTION DUE TO COMBUSTION CONTROL, BAGHOUSE CONTROL, AND ACTIVATED CARBON INJECTION. TWO SETS OF THREE POINTS INDICATED FROM 1994 TESTS AT DAYTON 1994 TEST DATA SHOW THE DIFFERENCE IN EMISSIONS WHEN OPERATING THE ESP AT 550°F VERSUS 392°F. (ENTROPY, 1994)

matter due to the catalytic activity of copper and iron. (Drum, 1994) (Gullett, 1994)

Dioxins can be generated from precursors (products of incomplete combustion) on or in particulate matter which is held at temperatures in the range from 300°F to 600°F which occurs on boiler and economizer surfaces, and in ESPs and even fabric filters; Avoiding retention on surfaces in these temperature ranges reduces formation. In addition, keeping the APC temperatures low permits organics such as dioxins to be condensed, absorbed or adsorbed on particulate matter which is then collected by the APC.

In summary, both combustion optimization and effective emission control are tools for reducing dioxin emissions from the stack.

Efforts to optimize combustion, such as those carried out by NITEP at the Quebec MWC, have demonstrated the drastic reduction in particulate carry-over which stable combustion under computer control can achieve. (NITEP, 1988) Associated with this are reduced emissions of carbon monoxide and other organics emissions, as well as reduction in the amount of volatile metals found in the flyash, resulting from lower and more stable furnace temperatures. Dioxin emissions were reduced as the result of the reduction in emissions of trace organics such as chlorobenzenes and chlorophenols. The monitoring of these organics may be useful in optimizing combustion and minimizing dioxin emissions. (NITEP, 1988)

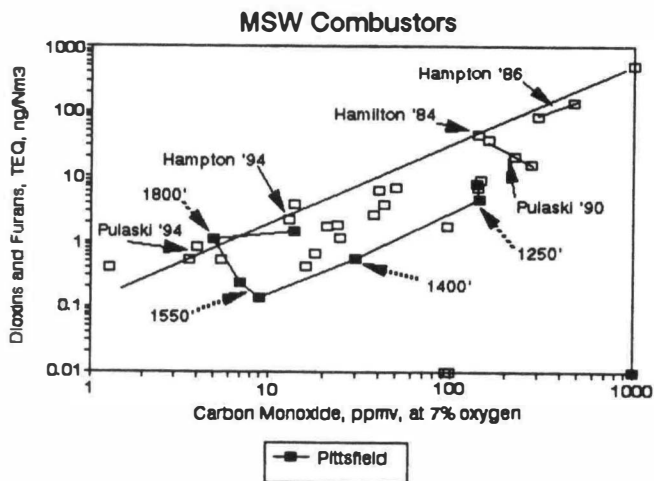


FIG. 3 TOXIC EQUIVALENT (TEQ) TCDD EMISSIONS FROM MWCS PLOTTED VERSUS CARBON MONOXIDE. DATA FROM TESTS OF MWCS WITH THREE DIFFERENT TECHNOLOGIES FALL CLOSE TO THE SAME STRAIGHT LINE. DIAGNOSTIC TESTS OF PITTSFIELD MWC FOLLOW TWO DIFFERENT LINES.

Combustion optimization. Operators have used carbon monoxide (CO) measurements as an indicator of effective combustion in their efforts to optimize combustion. Data recorded by the computer data logger can be analyzed to ascertain optimum operating conditions. Figure 3 shows the range of Toxic Equivalent (TEQ) TCDD reported from compliance tests of a wide range of facilities having ESPs. Test data from these specific but very different facilities fall close to a single line relating CO to TEQ.

The Pittsfield data show the range of emissions resulting from diagnostic tests performed over a wide range of operating conditions from minimum to maximum furnace temperatures. (Hasselriis, 1987) Modifications of the Hampton facility were primarily related to improvements made to overfire air injection and computer control. (Austin, 1994)

The modifications to the Pulaski facility include both substantial modifications to the supply and control of overfire and underfire air, coupled with computer control, and reduction in the operating temperature of the ESP. (Hasselriis, 1995) (ELI, 1994)

APC temperature reduction. The impact of APC temperature on emissions of TEQ is shown in Figure 4. The tendency of data points to fall on straight lines or into narrow, but linear, bands, supports the concept that emissions are kinetically controlled under the influence of temperature. This graph includes the data from Pulaski and Dayton, where air pollution control (APC) temperatures were reported along with TEQ. The Danish data cited by Boscak (1992) shows that emissions from two different MWCS having spray-dry scrubbers and baghouses exhibit a distinctive characteristic performance with temperature.

The following observations can be made regarding Figure 3:

- Data from tests of Hamilton (1984), Hampton (1986), Hampton (1994), and Pulaski (1994) fall close to the same straight line, indicating that Hamilton, burning refuse-derived fuel (RDF) on a traveling grate in a waterwall furnace with ESP; Hampton,

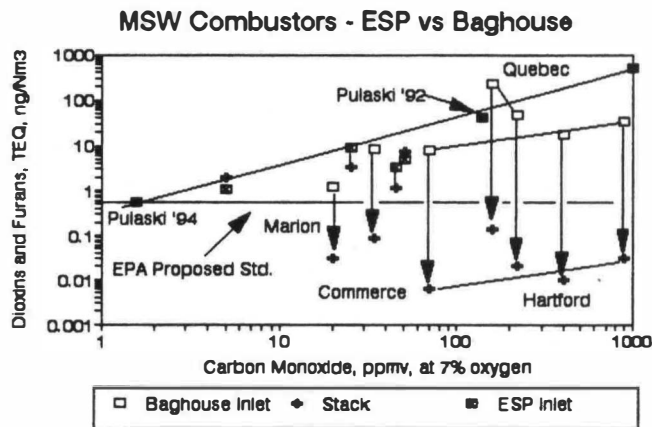


FIG. 4 TOXIC EQUIVALENT (TEQ) TCDD EMISSIONS VERSUS CARBON MONOXIDE, SHOWING INLET AND OUTLET LEVELS OF FACILITIES WITH ESPS VERSUS THOSE WITH SCRUBBER/BAGHOUSE EMISSION CONTROLS. ESPs SHOW BOTH REDUCTION AND INCREASE IN TEQ. MARION, COMMERCE, QUEBEC AND HARTFORD DATA SHOW A WIDE RANGE OF INLET CONDITIONS, INCREASING WITH CO, BUT FAIRLY CONSISTENT OUTLET CONCENTRATIONS AND REMOVAL EFFICIENCIES EXCEEDING 99%.

burning MSW on a stoker in a waterwall furnace with ESP; and Pulaski, burning MSW on a stoker in a refractory furnace followed by a water quench and an ESP (without a boiler), all exhibit similar characteristics.

- The Hampton data from tests in 1986 and 1994 show the 98% reduction in CO and 99.5% reduction in TEQ which resulted from improvements in combustion resulting from modification of the overfire air systems.
- The CO emissions of the Pulaski #5 unit were reduced from 143 ppm to 0.1 to 3.6 ppm (average 1.67), a 98% reduction, while the TEQ was reduced from 44 to 0.6 ng/dscm, a 98.6% reduction, by improving combustion air distribution and use of computer control, as well as ESP temperature reduction.
- Data from the diagnostic tests of the Pittsfield facility (having a refractory furnace and waste-heat boiler and, at that time an electrified gravel bed) show that the boiler exit TEQ varied along two lines relating CO to TEQ. (TEQ was calculated from total D/F) The lower line drawn through data at furnace temperatures ranging from 677°C (1292°F) to 843°C (1550°F) includes Pulaski 1990 data from Units #3 and #4. (Hasselriis, 1987)

The graph of CO versus TEQ indicates that the Pittsfield data at higher furnace temperatures were consistent with that of the other facilities, whereas the emissions at lower furnace temperatures were an order of magnitude lower. This is mainly because higher temperatures correspond to lower excess oxygen levels which produce greater quantities of furans.

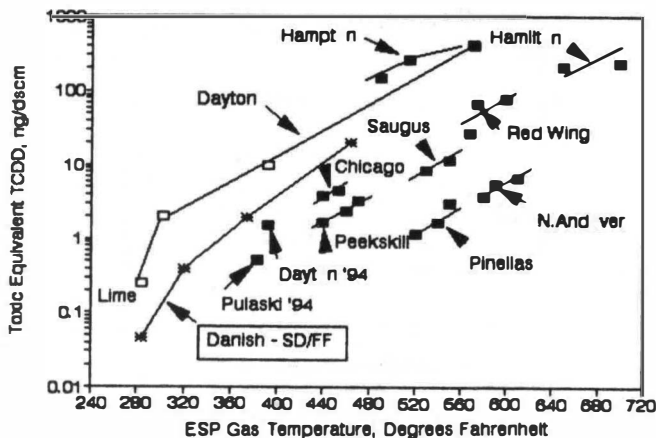


FIG. 5 TEQ EMISSIONS OF MWCs HAVING ESPs PLOTTED VERSUS TEMPERATURE OF FLUE GAS ENTERING THE APC. DAYTON 1990 DATA WITH LIME INJECTION SHOWS SUBSTANTIAL REDUCTION. DANISH DATA FROM PLANTS WITH SPRAY DRYER AND FABRIC FILTER (SD/FF) SHOW DIFFERENT CHARACTERISTICS. WASTE-TO-ENERGY (WTE) PLANT DATA FALL ALONG SEVERAL LINES HAVING THE SAME SLOPE, INDICATING COMBUSTION EFFECTIVENESS. PULASKI 1994 DATA REFLECT IMPROVED COMBUSTION AND TEMPERATURE REDUCTION FROM 1983 TO 1994; DAYTON 1994 TESTS SHOW SIMILAR REDUCTIONS.

Figure 6 shows the Pittsfield CO and total PCDD+PCDF emissions versus furnace exit temperature. (Hasselriis, 1987) Up to about 1500°F PCDD+PCDF follows the same trend with temperature as CO, but at higher temperatures little further reduction takes place, and at higher than 1750°F, PCDD+PCDF emissions increased ten-fold, reflecting an increase in furans. This leveling off may be attributed to poor mixing of the reactants, oxygen and combustible gases. Waterwall furnaces generally have flame temperatures in the 2000 to 2200°F range in order to achieve the required retention time at 1800°F: at these high temperatures, poor mixing at the reduced oxygen levels may also account for high DD/DF emissions.

Figure 5 compares TEQ concentrations at the inlets and outlets of facilities equipped with ESPs and scrubber/baghouses, versus carbon monoxide measured in the stack. The ESPs sometimes had outlet concentrations greater than those at the inlet, due to formation in the ESP. The facilities with baghouses which exhibited high CO levels did not have higher outlet dioxins than those with low CO levels, and all showed high removal efficiencies. The consistency of outlet TEQ reflects the fact that scrubber/baghouses remove dioxins as a function of temperature, and relatively insensitive to inlet concentrations.

When scrubbers remove dioxins, CO doesn't matter

The success in reductions in emissions of organics has been achieved primarily by the use of CO monitors, and due to the relationship between CO and dioxins which is often found. However, the NITEP tests at the Quebec MWC, and the

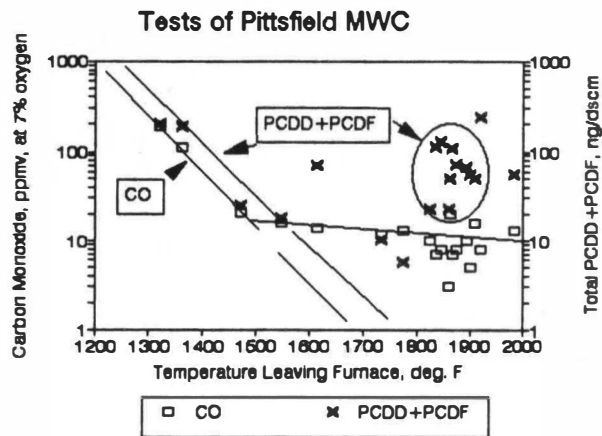


FIG. 6 CARBON MONOXIDE AND PCDD+PCDF DATA FROM DIAGNOSTIC TESTS AT PITTSFIELD PLOTTED VERSUS TEMPERATURE LEAVING FURNACE SHOW THAT INCREASED TEMPERATURE RESULTED IN LEVELING OFF OF CO, AND SHARP INCREASES IN PCDD+PCDF AT TEMPERATURES ABOVE 1800°F, PROBABLY INDICATIONS OF INADEQUATE MIXING OF COMBUSTIBLE GASES WITH OXYGEN.

EPA/NITEP tests of the RDF-burning facility at Hartford, show that the emission control device can also accomplish highly efficient control of dioxins in spite of CO readings greatly exceeding 150 ppm, and in spite of correspondingly high dioxin levels entering the APC due to less effective combustion. (NITEP, 1988, 1994)

Of course this means that the products of incomplete combustion reside in the collected flyash. In Europe disposal of flyash containing toxic compounds is closely regulated and discouraged. In the US, where landfills are readily available and closely regulated, the same imperatives do not apply.

Relationship between APC temperature and dioxins

The TEQ data from various MWCs having ESPs plotted versus the ESP gas temperature, as shown in Figure 6, reveal trends similar to those seen with CO. These observations may be made:

- Measurements of emissions from Pulaski units #3 and #4 (having a common stack) in the years 1992, 1993 and 1994 fall close to a single line.
- The 1989 and 1995 tests of Pulaski Unit #5 fall on a line ten-fold below this line, which includes data from Tulsa, Chicago and Saugus, which are waterwall MWCs with ESPs. (EPA, 1993) The spread between the two lines is related to combustion effectiveness.
- TEQ data from Tulsa, Pulaski, Pittsfield, Westchester and Pinellas show no trend with APC gas temperature. (EPA, 1993)
- The Dayton data closely match the Pulaski data.
- Data from tests of Danish MWCs having spray-dry scrubbers

Hartford RDF Tests

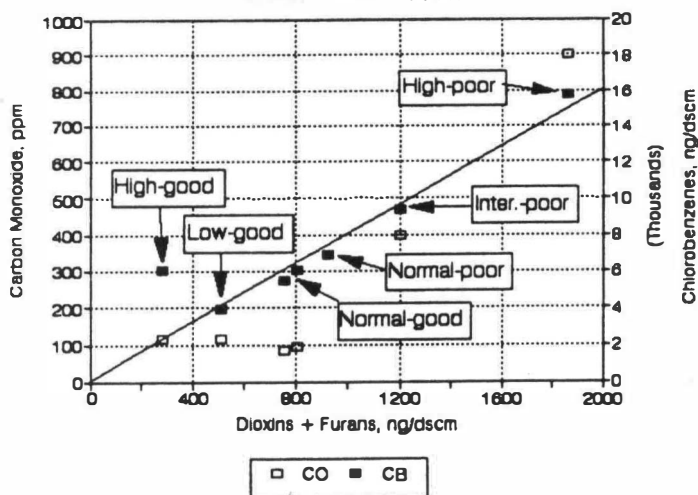


FIG. 7 CORRELATION OF CARBON MONOXIDE AND CHLOROBENZENES WITH DIOXINS PLUS FURANS, FROM NITEP TESTS OF HARTFORD RDF COMBUSTION FACILITY. TESTS WERE RUN AT LOW, NORMAL, INTERMEDIATE AND HIGH STEAMING RATES, AND AT GOOD AND POOR CONDITIONS. EACH POINT IS THE AVERAGE OF ONE TO THREE TEST RUNS.

with fabric filters are plotted for comparison, showing similar temperature effects on emissions. (Bosca, 1992)

Of course this means that the products of incomplete combustion reside in the collected flyash. In Europe disposal of flyash containing toxic compounds is closely regulated and discouraged. In the US, where landfills are readily available and closely regulated, the same imperatives do not apply.

From the above, it appears that when combustion is efficient, and precursor levels are low, TEQ is low, and the APC temperature has less or even no effect on TEQ emissions.

Chlorobenzene as a surrogate for dioxins

While CO has been found to be useful as an indicator of good combustion, and surrogate for dioxins under some conditions, it has been observed that at low CO levels dioxins and furans often increase, without relationship to CO. Analysis of data obtained at Pittsfield showed that chlorobenzenes (CB) exhibited a 94% correlation with dioxins. (NYSERDA, 1987)

Analysis of the data obtained from the tests at Hartford also shows a correlation between CB and dioxins. A total of fourteen test runs were carried out during which operating parameters were varied and gases entering and leaving the scrubber/baghouse analysis were analyzed for the acid gases, metals and organics. (NITEP, 1994) Runs at low, intermediate, normal and high steam generating rates were performed, ranging from 73,000 kg/h (low) to 107,000 kg/h (high). At each load condition from one to three runs were under good conditions, and at the intermediate, normal and high loads, runs under poor conditions were performed. These data are shown in Figure 7, which shows the averages of data obtained during tests under seven different performance test conditions. The CB data show a linear relationship with total dioxins plus furans down to 500 ng/dscm. One single run, "high-

good" stands alone. The CO data falls on a straight line with D+F from 100 ppm to 900 ppm, as D+F range from 800 to 1900 ng/dscm. However, CO remains at 100 ppm as dioxins were reduced below 800 ng/dscm. The fact that a linear relationship between CB and D+F was found in six out of seven tests indicates that this relationship might be useful, that is, CB measurements might serve as a practical surrogate for dioxins. This finding indicates that a continuous CB monitor, which can now be obtained, might be more useful in diagnostic testing and optimization of waste combustion facilities than a CO monitor.

SUMMARY AND CONCLUSIONS

There is good reason to believe that the performance of existing MWCs which lack acid gas controls and baghouses can be upgraded by economical means sufficiently to meet the EPA guidelines for existing MWCs, and even to meet State requirements which may be more stringent. The high cost and often impracticality of installing spray-dry scrubbers and baghouses militates against application of these BACT systems, when alternatives are available which can be installed and operated at much lower cost with minor modifications to the facility.

Acid gas control can be provided by furnace and/or duct injection of reagents suitable for control of SO₂ and HCl, and by APC temperature reduction. Recirculation of ESP products may compensate for the lack of the retention time which baghouses provide.

For many facilities having ESPs and no acid gas controls, emissions of dioxins and furans, either total or toxic equivalent, were found to vary directly with CO in the range from 1000 ppm to as low as 1 or 2 ppm, provided that good mixing was maintained. However, emissions from facilities with dry injection and spray-dry scrubbers were found to be independent of CO, and basically dependent upon the temperature which the scrubbers were operated. This indicates that regardless of CO, scrubbers can remove organics almost completely, by adsorption absorption and condensation, primarily as a function of the scrubber temperature.

Optimization of combustion can be achieved by the use of continuous monitors, most importantly the CO monitor, for diagnostic purposes. Substantial improvements can be made by redesigning overfire air ports and air distribution to underfire and overfire air, along with provision of automatic control dampers and computer controls of combustion air and stoker actions. The characteristic of this relationship has been found to vary with the technology, however, for reasons which are not readily apparent.

The temperature at which the ESP is operated has been found to be strongly correlated with emissions of not only acid gases and volatile metals such as mercury, but also dioxins and furans. However, the absolute level of emissions at a given ESP temperature is found to depend strongly upon the combustion technology. Toxic equivalent TCDD emissions from ESPs were noted to be reduced by two orders of magnitude as temperatures were reduced. The same is true for total dioxins plus furans.

Continuous measurements of CO, SO₂, HCl and NO_x in the gaseous products of combustion are useful for optimization of combustion control, as well as for performing studies in the effectiveness of various dry reagent injection schemes. They offer the owners and operators of existing facilities the means for performing research, on site, and demonstration of the practicality of emission control options. Data recorded by a data logger can be analyzed as a tool for optimization.