Catalytic Destruction of PCDD/F

Laboratory Test and Performance in a Medical Waste Incinerator

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Introduction

As an end-of-pipe technique for removing PCDD/F (polychlorinated dibenzo-dioxin/furan) from industrial combustion sources, activated carbon injection has been the popular choice for PCDD/F emission control[1]. However, activated carbon fails to solve the fundamental problem – the total release of dioxin to the environment. A better technique is catalytic destruction using oxidation or reduction catalysts. Selective catalytic reduction (SCR) honeycomb systems have been adopted for NOx control and more recently, dioxin control. However, high capital costs and operating costs relative to activated carbon have delayed its widespread use.

W. L. Gore & Associates, Inc. (Gore) recently commercialized the REMEDIA™ D/F catalytic filter system, which catalytically destroys PCDD/F with very high efficiency, while simultaneously removing dust from the waste gas stream by membrane filtration[2]. The system has been tested extensively in Europe, Japan, and the United States in the past five years. These tests have demonstrated high PCDD/F removal efficiency, low maintenance, and long performance life. It is the most cost-effective technique to control PCDD/F emissions in the incineration industry.

This paper presents laboratory test results on a powder catalyst using a dioxin model compound and commercial experience at the Phoenix Services (Baltimore Regional) Medical Waste Incinerator in Baltimore, Maryland. The laboratory study of the REMEDIA D/F Catalytic Filter System is presented elsewhere in this volume[3].

Materials and Methods

The catalyst used in the laboratory experiments and the REMEDIA D/F catalytic filter system is derived from V_2O_5/TiO_2. The REMEDIA filter manufacturing process is reported elsewhere[2]. A plug flow reactor system was designed to test the catalyst powder in a horizontal quartz reactor. The system can inject dioxin compounds at a constant rate and very low concentration (< 100 ppb). Figure 1 shows the system diagram. In a typical experiment, 10 mg of catalyst powder is loaded in a 5 cm x 4 mm (id) quartz reactor giving a catalyst bed measuring 2 mm long x 4 mm in diameter. Taking into account gas flow rate, mean catalyst particle size, and reactor geometry, fluid dynamic calculations show that a plug flow model was appropriate for this system. The gas mixture contained 10% oxygen, 90% nitrogen. The flow rate was 30 cc/min and the reactor temperature was 230˚C. For each test, 25 ng (62 ppb) of 1,2,3,4-TCDD (tetrachlorinated dibenzo-dioxin) was introduced over a 10-minute period. To collect and concentrate the condensable fraction of the exhaust, the reactor effluent was passed through a cryogenic trap cooled to -130˚C. The collected material was transferred to an in-line GC (gas chromatography) through a splitless injector interface for simultaneous GC/FID (flame ionization detector) and GC/MSD (mass selective detector) analysis.

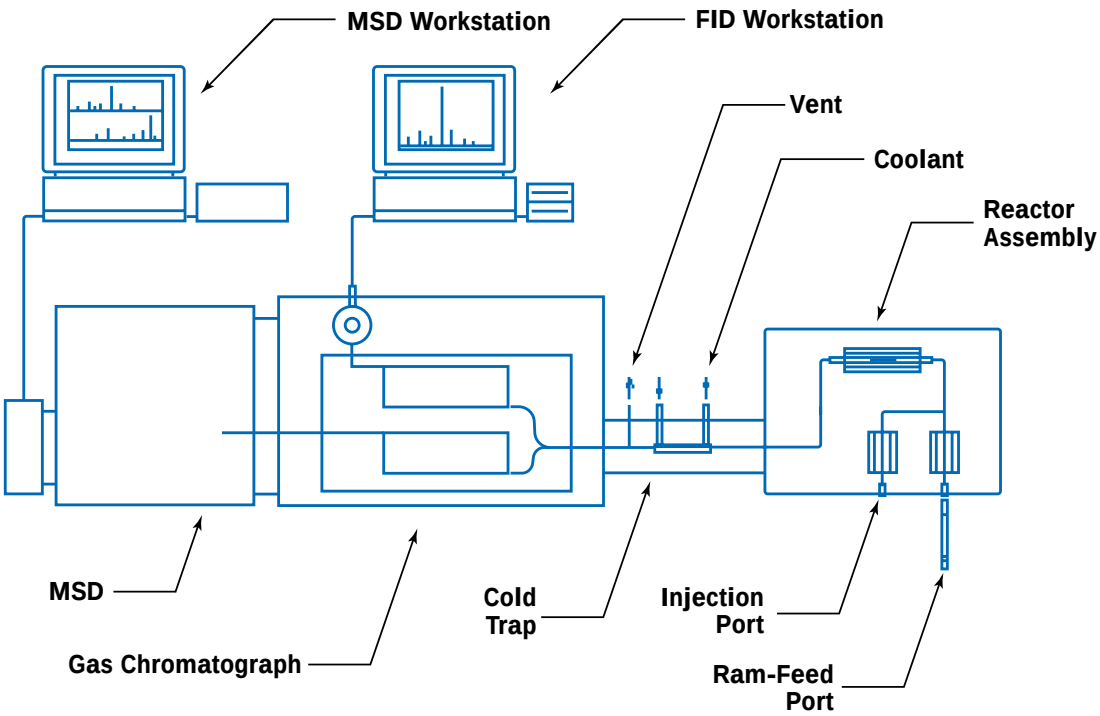

Figure 1. A general schematic of the University of Dayton Research Institute (UDRI) Advanced Thermal/Photolytic Reactor System (ATPRS) configured with a heterogeneous catalyst reactor and ram-feed system.

Phoenix Services Medical Waste Incinerator

The Phoenix Services Medical Waste Incinerator processes regulated medical waste and general waste from hospitals and clinics in Baltimore, Maryland, and regulated medical waste from health care institutions throughout the mid-Atlantic area of the United States.

This plant, which began commercial operation in January of 1991, is the largest dedicated medical waste incinerator in the world. The process consists of two identical controlled air-type incineration lines, each with a nominal-processing rate of 77 metric tons of waste per day. The entire facility is permitted to process 136 metric tons of waste per day.

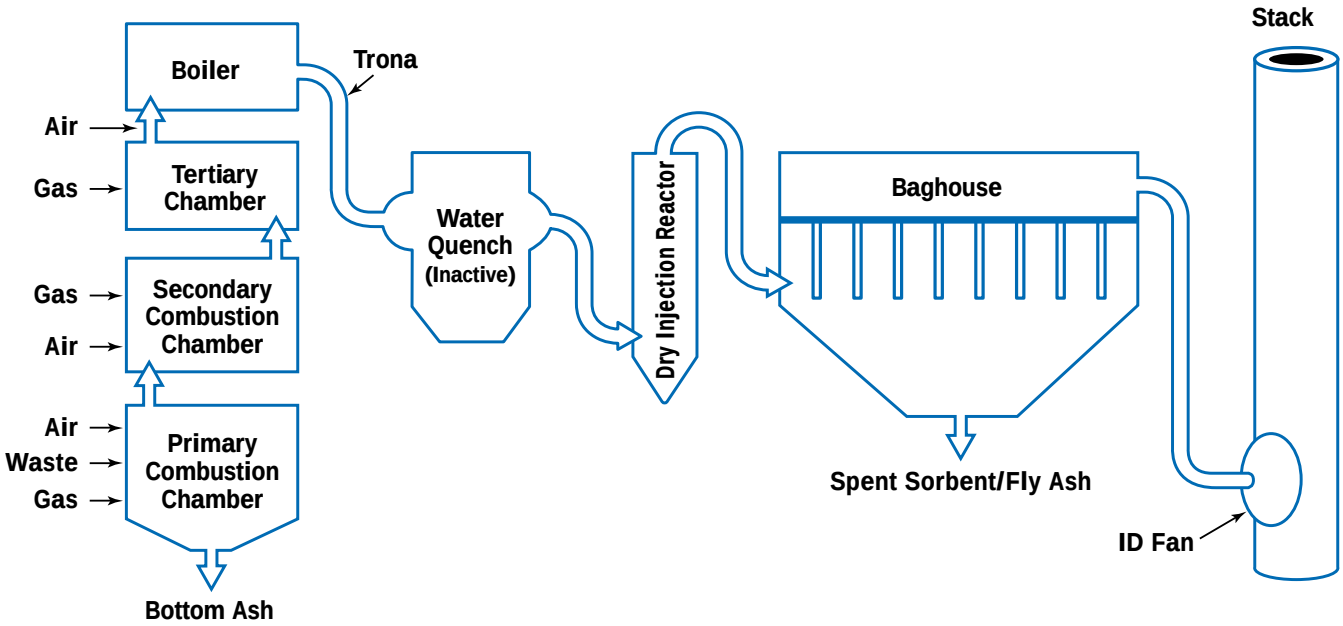

Figure 2. Plant configuration for the Phoenix Services Medical Waste Incinerator (natural gas input is used only for startup and shutdown).

In September 1997, the US EPA promulgated new source performance standards and emission guidelines for new and existing hospital/medical/infectious waste incinerators. The new regulation imposes concentration-based limits for PCDD/F at 1.76 ng/Nm^3 @ 11% O_2. The historical level of PCDD/F measured at the facility is considerably higher than the new limit. In May 1999, the plant purchased the REMEDIA D/F catalytic filter system. After 9 months of continuous operation, a PCDD/F measurement was performed in January 2000. Two sampling locations were chosen: baghouse inlet duct (raw gas) and stack (clean gas). The two locations were sampled simultaneously. Two sampling runs were performed for each location. The sampling method employed was according to US EPA Method 23. Analyses to determine total PCDD/F were performed using high resolution GC/MSD. The baghouse temperature during the measurements was between 194˚C and 204˚C.

Results and Discussion

In the laboratory experiments, three reactors were loaded separately in the system and each reactor was run four times under the reaction conditions described above. The experiments were run under the typical flow rate-to-catalyst ratio used in commercial applications. All the tests on the reactors showed no measurable TCDD in the reactor effluent. Further, there was no other organic species detected from the exhaust. This indicates the TCDD was destroyed with an efficiency of greater than the system detection limit of 99.6%, and that only inorganic products (i.e., carbon dioxide, water, etc.) were formed. This is consistent with other work that has shown the vanadia catalysts are highly active in the oxidation of chlorinated organic compounds, including dioxins [4,5].

To determine if any extractable TCDD was present on the catalyst, following the reactor test each reactor was removed and subjected to Soxhlet extraction for 24 hours using methylene chloride. The extracted material was reduced to dryness at room temperature under dry air and transferred to a solids sampling probe with several aliquotes of methylene chloride. No detectable TCDD from any of the extracts was observed.

Results from the Baltimore Medical Waste Incinerator

Figure 3 presents total PCDD/F concentrations (solid + gas phase) in the raw gas and clean gas. The data are presented as I-TEQ values.

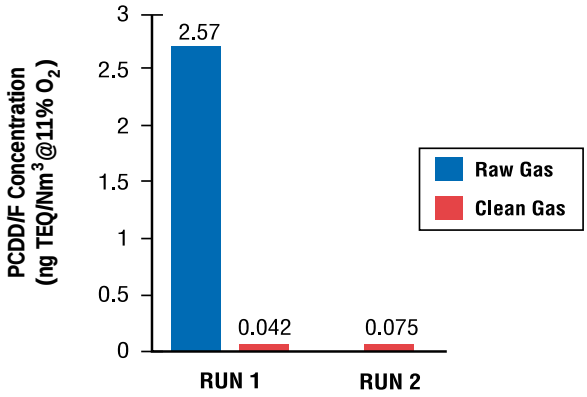

Figure 3. Total PCDD/F concentrations (solid + gas phase) in the raw gas and clean gas.

Figure 4 presents the total PCDD/F emissions in the stack for the current study, where the baghouse is equipped with the catalytic filter system. This value is compared with the new EPA emissions guideline for existing medical waste incinerators and the average historical value measured in 1998. The PCDD/F emission with the catalytic filter is more than one order of magnitude lower than both the new EPA limit and the historical average. The emission is also lower than the European standard of 0.1 ng TEQ/Nm³ @ 11% O_2.

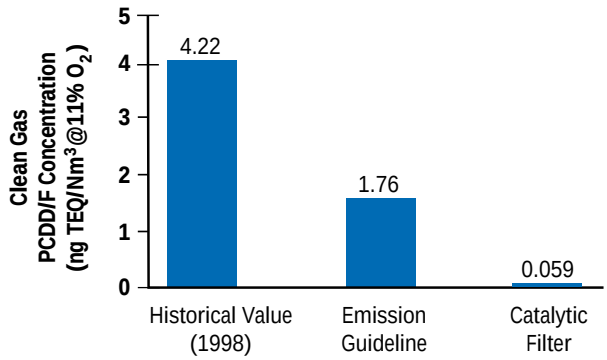

Figure 4. Total PCDD/F stack emissions using the catalytic filter system.

Conclusions

The results from both catalyst powder test experiments and the commercial measurements showed very high PCDD/F removal efficiency by the REMEDIA D/F catalytic filter system. The catalyst destroys the PCDD/F to form harmless carbon dioxide and water. The filter system is very effective, able to meet the most stringent emission limit of 0.1 ng TEQ/Nm^3. The system can maintain the high efficiency for long periods without deactivation. The total PCDD/F removal efficiency of more than 99% and 99.95% PM removal efficiency make it the most cost-effective way to control PCDD/F and particle emissions in medical or municipal waste incinerators.

Acknowledgements

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