36870 PDF

TESTING THE SONOTECH PULSE COMBUSTOR IN A PILOT-SCALE ROTARY KILN INCINERATOR

Marta K. Richards
United States Environmental Protection Agency
Office of Research and Development, Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268
513/569-7692

Larry R. Waterland
Acurex Environmental Corporation
Incineration Research Facility
Jefferson, Arkansas 72079
501/541-0004

Kenneth G. Partymiller
PRC Environmental Management, Inc.
5326 Paris Pike
Georgetown, Kentucky 40324
502/867-1397

INTRODUCTION

This is a report on an incinerator performance test of an innovative soundwave-based combustion burner system that was patented, designed, and fabricated by its developer - Sonotech, Inc., of Atlanta, Georgia. The Superfund Innovative Technology Evaluation (SITE) program Demonstration of the Sonotech, Inc., tunable-pulse combustion burner technology was conducted in the fall of 1994 at USEPA's Incineration Research Facility (IRF) in Jefferson, Arkansas. Sonotech claims the technology will provide benefits when applied in a variety of combustion processes. The burner system incorporates a natural-gas-fired burner, the pulse frequency of which can be tuned to induce large amplitude sonic pulsations inside a combustion process unit, such as an incinerator. Sonotech claims these pulsations will increase the efficiency of a combustion process by promoting better mixing of the combustion gases. In the SITE Demonstration of its technology, Sonotech's technicians retrofitted a pulse combustion burner in the government's pilot-scale rotary kiln incineration system (RKS) housed at the IRF.

Sonotech claims their burner significantly improves the performance of the incineration process by increasing the rates of mixing (i.e.,momentum) and mass and heat transfers within an incinerator. These, in turn, increase the incineration rate, reduce the amount of air required for incineration, reduce the severity of puffs, and reduce pollutant emissions. The developer claims these improvements reduce capital investment and operating costs in a wide variety of incineration systems and improve their performance.

TEST OBJECTIVES

The general test program objective was to develop test data to allow objective and quantitative evaluation of the Sonotech claims for their pulse combustion technology. For the Primary Test Program Objectives, we investigated whether the Sonotech technology, when applied to the IRF RKS and compared to conventional, non-pulsating combustion, results in:

- Increased incinerator capacity or productivity
- Increased principal organic hazardous constituent (POHC) destruction and removal efficiency (DRE)
- Decreased flue gas carbon monoxide (CO) emissions
- Decreased flue gas nitrogen oxides (NO_x) emissions
- Decreased flue gas soot emissions
- Decreased combustion air requirements
- Decreased auxiliary fuel requirements

Test data were also developed for the Secondary Test Program Objectives, which were to allow evaluating whether the application of the Sonotech technology, when compared to conventional, non-pulsating combustion:

- Reduced the magnitude of transient puffs of CO and total unburned hydrocarbon (TUHC)
- Allowed reduced incineration costs
- Caused significant changes in:
  - Distribution of hazardous constituent trace metals among the incineration system discharge streams (kiln bottom ash, scrubber liquor, baghouse flyash, and baghouse exit flue gas)
  - The mobility of the toxicity characteristic leaching procedure (TCLP) trace metals from kiln bottom ash, scrubber liquor, and baghouse flyash

The last secondary objective does not relate to any Sonotech claim, however, fates of metals and their leachabilities are of general interest to the EPA IRF research program.

TESTING PROTOCOL

The waste feed for all tests was a mixture of contaminated materials from two manufactured gas plant (MGP) Superfund sites. One site was the Peoples Natural Gas Company (coal gasification) site in Dubuque, Iowa, and the other was an oil gasification site in the Southeast U.S. The final waste feed was composed of coal and sludge from the Peoples site mixed with the contaminated soil borings and tar from the oil gasification site.

The final composite feed contained polynuclear aromatic hydrocarbons (PAHs) and other semivolatile organic compounds (SVOCs), benzene and other volatile organic compounds (VOCs), metals, and other contaminants. It was determined that, to guarantee meaningful calculation of DREs of specified POHCs, spiking of the waste feed with benzene and naphthalene was necessary. The spiked composite feed contained 13,500 mg naphthalene/kg feed and 9000mg benzene/kg feed.

Twelve field incineration test runs were conducted. Four incinerator system operating conditions - each in triplicate - addressed the Demonstration objectives. The four conditions were:

- Condition 1: Conventional combustion at baseline/typical operation
- Condition 2: Conventional combustion at its maximum feedrate
- Condition 3: Sonotech combustion at the same feedrate as Condition 2
- Condition 4: Sonotech combustion at its maximum feedrate

This testing program would allow comparison of Sonotech performance with conventional combustion and permit evaluation of the developer performance claims.

Table 1 shows the samples that were taken and the analyses that were performed.

TABLE 1. SAMPLING AND ANALYTICAL TEST PROGRAM

Samples \ Analyses	SVOCs	VOCs	Metals	PCDDs/PCDFs	TOC	TCLP
Feed	X	X	X			X
Kiln Ash	X	X	X			X
Scrubber Liquor	X	X	X			X
Baghouse Ash	X	X	X			X
AB Exit Particulate	X				X	
BH Exit Flue Gas	X	X	X			
AB Exit Flue Gas	X	X	X	X		

Note: SVOCs = Semivolatile Organic Compounds
VOCs = Volatile Organic Compounds
PCDDs/PCDFs = Polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans
TOC = Total Organic Carbon
TCLP = Toxicity Characteristic Leaching Procedure of metals
AB = Afterburner
BH = Baghouse

To determine if performance satisfied the test objectives, continuous emission monitors (CEMs) constantly measured the oxygen (O_2), CO, carbon dioxide (CO_2), NO_x, and TUHC levels in the flue gas streams.

The test matrix was designed to give data that allowed evaluation of the vendor claims as follows. Test condition 1 provided emissions, POHC DRE, metals partitioning, and metals leachability data corresponding to baseline, typical, well-controlled incinerator operation. Test condition 2 provided the same kinds of data for operation corresponding to maximum feedrate possible under conventional incinerator operation, which is borderline acceptable operation approaching noncompliance with typical permit limits. Test condition 3 provided similar data corresponding to test condition 2, except with the Sonotech unit running, while test condition 4 corresponds to the maximum feedrate possible with the Sonotech pulse combustor operating.

RESULTS

Preliminary results of the test program related to the primary test objectives are reported here. Test condition 3 data are used to evaluate the last six primary objectives by comparing results with the those obtained under test conditions 1 and 2 data. Comparing test condition 4 data to those from test conditions 1, 2, and 3 allowed evaluation of the first primary objective. The numerical-average results are shown in Table 2.

TABLE 2. OPERATING DATA AND RESULTS BY TEST CONDITION

Parameter	Test Conditions*			
	Conventional Combustion		Pulse Combustion	
	1:	2:	3:	4:
Waste feedrate, lb/hr	61.0	72.8	73.6	82.4
Kiln Gas temperature, °F	1,720	1,730	1,700	1,700
Afterburner gas temperature, °F	2,000	2,000	2,000	2,000
Afterburner exit O_2, %	9.33	9.27	8.73	8.51
Heat Input, kBtu/hr				
Waste	517	617	639	699
Auxiliary fuel	1,670	1,540	1,580	1,490
Total	2,190	2,160	2,220	2,190
Combustion air, dscf/hr	37,300	36,800	35,700	35,200
Afterburner exit CO, ppm @ 7% O_2	15.2	20.3	14.5	17.9
Afterburner exit NO_x, ppm @ 7% O_2	90.0	81.7	78.1	72.4
Afterburner exit soot emission rate (TOC in particulate, %)	<1.0	$\leq$2.4	$\leq$1.0	$\leq$2.1

* Each Data Point is the Numerical Average of 3 Tests
1: Baseline Feedrate
2: Maximum Feedrate with Conventional Combustion
3: Condition-2 Feedrate
4: Maximum Feedrate with Pulse Combustion

1. Incinerator capacity and productivity, shown in Table 2 - measured in terms of tested waste feedrate, showed an increase with pulse combustion of 20%, comparing test condition 3 with test condition 1 and an increase of 13%, comparing test condition 4 to condition 2. In addition, when comparing test condition 4 to test condition 1, the empirical data show that increasing the feedrate while using the pulse combustor resulted in a productivity increase of about 35% with similar resulting CO, NO_x, soot, VOC, and SVOC emission levels.

2. POHC DRE evaluations were inconclusive. Measured at the afterburner exit, benzene DREs for all 12 test runs were greater than 99.994% with a slight improvement in the third decimal place for the Sonotech burner. Naphthalene DREs were greater than, or equal to, 99.999% for all test conditions.

3. The average afterburner exit CO emissions decreased marginally with the operation of the Sonotech combustor.

4. NO_x emissions were low in all tests, but the average NO_x emissions with the pulse combustor in operation were slightly lower than those from conventional combustion.

5. Average soot emissions, measured by TOC analyses of the afterburner exit flue gas particulate and comparing soot emission rates, were lower with pulse combustion than conventional combustion at equivalent feedrates.

6. Combustion air requirements, determined from stoichiometric calculations, showed small decreases with pulse combustion.

7. Fuel requirements for all four test conditions were statistically similar.

For the secondary test program objectives:

1. The frequency of transient puffs of CO decreased with the pulse combustor in operation.

2. The average normalized distribution of the trace metals did not vary significantly from test to test.

3. The effect of the Sonotech combustor on incinerator residue toxicity characteristics, as measured by the TCLP, was inconclusive due to very low levels of metals in the kiln ash and, therefore, the leachate.

CONCLUSIONS

The most important difference measured with the Sonotech combustor in operation was the ability to increase the capacity of the EPA RKS. This increased capacity resulted in the same or slightly reduced CO, NO_x, and soot emissions. Additionally, the benzene and naphthalene DREs were equal or marginally improved with the Sonotech burner in operation. The increase in incinerator capacity was also realized without increasing fuel or air consumption to the system.

FOR MORE INFORMATION:

Marta K. Richards
United States Environmental Protection Agency
Office of Research and Development, Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268
513/569-7692

THE RELATIVE EFFECTIVENESS OF MINERAL-BASED SORBENTS FOR METAL CAPTURE IN A BENCH-SCALE INCINERATOR

Gregory J. Carroll
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
Cincinnati, OH 45268
513/569-7948

Shyam Venkatesh
Acurex Environmental Corporation
c/o NCTR, Bldg. 45
Jefferson, AR 72079
501/541-0004

INTRODUCTION

Given the concern over the emission of hazardous constituent trace metals from incinerators, there is currently considerable interest in the potential use of mineral-based sorbents for capturing and retaining those metals in the incinerator "ash" discharges (fly ash and bottom ash).

Most of the research completed to date has focussed on quantifying the effectiveness of various proposed sorbents for capturing vaporized metals from the flue gas. In such applications, it is theorized that vaporized metals will react with the sorbent particles at elevated incinerator temperatures or heterogeneously condense onto the sorbents as the flue gas cools. In the absence of available condensation sites, vaporized metals will primarily undergo homogeneous condensation, forming a fine fume. Thus, the goal with flue-gas sorbents is to make particles available with which the metals can react or upon which the metals can condense. Metals bound to larger sorbent particles will be more effectively collected by air pollution control systems (APCSs) than metals presented as a fine fume. Studies completed to date suggest that chemical reaction between the metal and the sorbent dominates over physical adsorption, offering the additional advantage of reduced potential for metal leaching from collected particulate.

Other researchers have studied the incorporation of sorbents into the solid feed. This approach seeks to capture and bind the metals in the incinerator bottom ash, preventing them from exiting with the combustion gases. Research completed to date suggests that for this approach to be effective, the metal should become volatile in the incinerator environment and chemically react with the sorbent material.

The subject test program was designed to further investigate this second approach by screening several minerals for their suitability as sorbent materials for capturing metals in the solid bed and preventing their release to the flue gas. In addition to capturing the metals, an ideal sorbent would retain them in the ash when disposed, so that extraction of the ash by the toxicity characteristic leaching procedure (TCLP) would yield a leachate with metals concentrations below respective regulatory levels. Accordingly, the objective of this screening program was to evaluate several candidate sorbents with respect to: [1] the degree to which they facilitate retention of trace metals in the ash/solid bed discharged from an incinerator; and [2] the degree to which they retain trace metals in the solid bed when subjected to TCLP extraction.(1)

METHODOLOGY

Test Equipment

The screening tests comprising this program were conducted in the bench-scale thermal