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EPA

SITE Technology Capsule

Sonotech Pulse Combustion System

Introduction

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, which is committed to protecting human health and the environment from uncontrolled hazardous waste sites. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. SARA mandates cleaning up hazardous waste sites by implementing permanent solutions and using alternative treatment technologies or resource recovery technologies to the maximum extent possible.

State and federal agencies and private organizations are exploring a growing number of innovative technologies for treating hazardous wastes. These new innovative technologies are needed to remediate the more than 1,200 sites on the National Priorities List, which involve a broad spectrum of physical, chemical, and environmental conditions requiring diverse remedial approaches.

The U.S. Environmental Protection Agency (EPA) has focused on policy, technical, and informational issues related to exploring and applying new technologies to Superfund site remediation. One EPA initiative to accelerate the development, demonstration, and use of innovative technologies for site remediation is the Superfund Innovative Technology Evaluation (SITE) program.

EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment and site remediation technologies. The Technology Capsules assist EPA remedial project managers, EPA on-scene coordinators, contractors, and other remedial managers in the evaluation of site-specific chemical and physical characteristics to determine a technology's applicability for site remediation.

This Technology Capsule provides information on the Sonotech Pulse Combustion System, which includes the patented Cello® pulse burner, developed by Sonotech, Inc. (Sonotech), of Atlanta, Georgia. Sonotech claims that its combustion system can be beneficial in a variety of combustion processes. The system incorporates a combustor that can be tuned to induce large amplitude sonic pulsations inside combustion process units, such as boilers or incinerators. According to Sonotech, these pulsations increase heat release, mixing, and mass transfer rates in the combustion process, resulting in faster and more complete combustion. Sonotech has targeted waste incineration as a potential application for the system. To test its potential applicability and effectiveness on a Superfund waste, the Sonotech pulse combustion system was demonstrated on a pilot-scale rotary kiln incineration system (RKS) at the EPA Incineration Research Facility (IRF) in Jefferson, Arkansas. In the demonstration, a Sonotech pulse combustion system was retrofit to the primary combustion chamber of the RKS.

SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

This Technology Capsule presents the following technology information:

- Abstract
- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Sources of further information

Abstract

Sonotech has targeted waste incineration as a potential application for this technology. Based on bench-scale rotary-kiln simulator tests, Sonotech proposed a demonstration under the SITE program to evaluate the Sonotech pulse combustion system on a larger scale at EPA's IRF in Jefferson, Arkansas.

The primary objective of the SITE program demonstration was to develop test data to evaluate the Sonotech pulse combustion system's treatment efficiency compared to conventional combustion. Test data were evaluated to determine if the Sonotech pulse combustion system (1) increased incinerator capacity, (2) increased destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHC), (3) decreased flue gas carbon monoxide emissions, (4) decreased flue gas nitrogen oxides emissions, (5) decreased flue gas soot emissions, (6) decreased combustion air requirements, and (7) decreased auxiliary fuel requirements.

The secondary objective of the demonstration was to develop additional data to evaluate whether the Sonotech system, compared to conventional combustion, (1) reduced the magnitude of transient puffs of carbon monoxide and total unburned hydrocarbons (TUHC); (2) significantly changed the distribution of hazardous constituent trace metals among the incineration system discharge streams (including kiln bottom ash, scrubber liquor, and baghouse exit flue gas), (3) changed the leachability of the toxicity characteristic leaching procedure (TCLP) trace metals from kiln ash, (4) reduced the incineration costs, and (5) was reliable.

To achieve the demonstration objectives, tests were performed in triplicate at four different incineration system operating conditions, for a total of 12 individual tests. The four test conditions included (1) conventional combustion at typical operating conditions and feedrate; (2) conventional combustion at its maximum feedrate; (3) Sonotech pulse combustion at the conventional combustion maximum feedrate, the same nominal feedrate as condition (2); and (4) Sonotech pulse combustion at its maximum feedrate.

The Sonotech pulse combustion system increased the incinerator waste feedrate capacity by 13 to 21 percent compared to conventional combustion. In addition, visual observations indicated improved mixing in the incinerator cavity with the Sonotech system operating.

The SITE program demonstration also revealed that, compared to conventional combustion, the Sonotech pulse combustion system reduced combustion air requirements as well as overall emissions of carbon monoxide, nitrogen oxides, and soot. Many of the data regarding the reduced emissions were within the precision of the measurement methods.

Technology Description

A pulse combustor typically consists of (1) an air and fuel inlet section including pressure-controlled flapper valves, (2) a combustion section, and (3) an exhaust section (see Figure 1). The entire unit can be added to an existing combustion process unit such as an incinerator. For this demonstration, the pulse combustor exhaust pipe was inserted into the rotary kiln combustion chamber of the incinerator.

The operation of pulse combustion is controlled by a complex interaction between an oscillating combustion process and acoustic waves that are excited inside the combustor. In the Sonotech pulse combustion system, fuel oxidation and heat release rates vary periodically with time, producing periodic variations or pulsations in pressure, temperature, and gas velocity. The pulse combustor sustains a cyclic combustion process by modulating the inflow of reactants (air and fuel) into the combustion section. Figure 1 depicts the phases of a single pulse of a pulse combustor. Sonotech claims that large amplitude resonant pulsations excited by its tunable pulse combustor can significantly improve an incinerator's performance, thereby reducing capital investment and operating costs for a wide variety of incineration systems.

With the pulse burner combustion section at atmospheric pressure, operation is initiated by sequentially introducing air and fuel. Initially, the mixture is ignited by a spark plug inside the combustor, producing a rapid pressure rise that closes the flapper valves and initiates a flow of gases into the exhaust pipe. The outflow of gases through the exhaust pipe decreases the pressure in the combustion chamber.

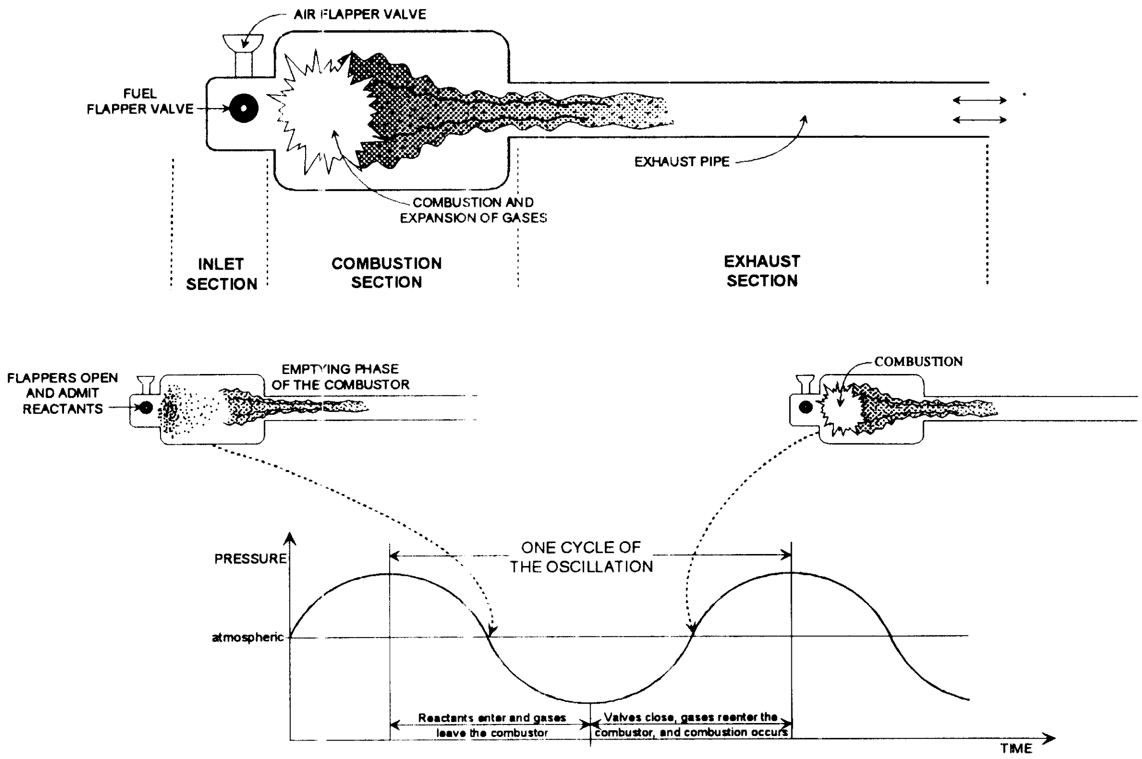

Figure 1: Operation of a Pulse Combustion System

When the combustion-produced pressure rise becomes less than the outflow-produced pressure decrease, combustor pressure begins to decrease. When the combustor pressure reaches its minimum value, the flow of gases in the exhaust pipe reverses direction and gases in the exhaust pipe re-enter the combustor.

As the combustor pressure drops, the valves open and admit new charges of fuel and air. These mix rapidly and ignite as they come into contact with pockets of burning gases left over from the initial cycle. Ignition is followed by combustion and a pressure rise similar to that in the initial cycle. The initial cycle is completed at the instant when the increasing pressure equals the atmospheric pressure. This periodic (pulsed) combustion process continues indefinitely without the need of the spark plug.

To excite large amplitude pulsations inside an incinerator, the pulse combustor must operate at a frequency that equals one of the natural acoustic modes of the incinerator. When this condition is satisfied, the incinerator is in resonance. Creation of large amplitude pulsations is achieved by (1) retrofitting a frequency-tunable pulse combustor through a wall of the incinerator and (2) varying its frequency until one of the natural acoustic modes of the incinerator is excited. The desired resonant operating condition is established by using one or more pressure transducers to monitor changes in the amplitude of pulsations inside the incinerator in response to changing the pulse combustor frequency. The desired operating condition is reached when the transducers indicate that the amplitude of pulsations inside the incinerator has been maximized.

Typically, pulse combustors can oscillate with frequencies that vary from 20 to several hundred cycles per second. These oscillations cause acoustic waves to form inside the combustor as its pressure increases above and decreases below atmospheric pressure.

Pulse combustion can be applied to a range of combustion processes such as boilers, dryers, calciners, and incinerators. In such applications, the pulse combustor can be used as the process burner, supplying all of the heat input to the process, or it can be a secondary burner that is used to excite pulsations in the combustion process. When used as a secondary burner, the pulse combustor delivers only a fraction of the main combustion process heat input (as little as 2 percent), while still exciting resonant pulsations in the process combustor. The remaining heat input is supplied by the conventional burner and other process feed streams.

For the SITE demonstration, a Sonotech pulse combustion system was used as the pulse generator for the RKS. Figure 2 presents a process schematic of the Sonotech pulse combustion system installed on the RKS. The RKS consists of a rotary kiln primary combustion chamber, a

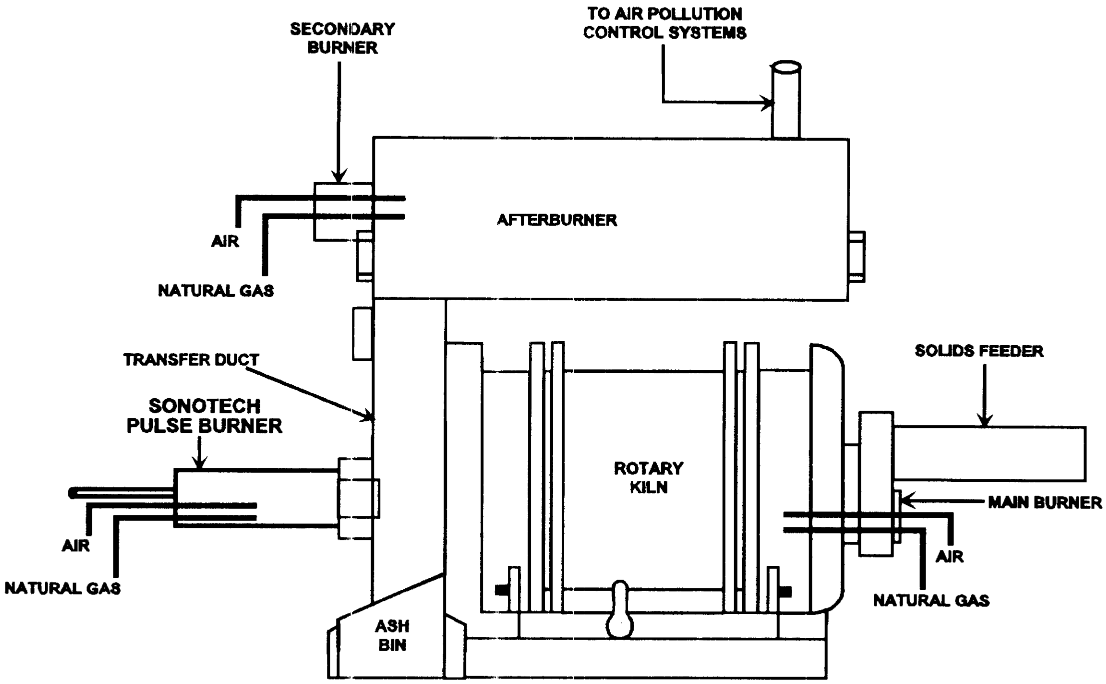

Figure 2: *The Sonotech Pulse Combustion System Fitted to the IRF RKS*

transition section, a fired afterburner chamber, and a quench section followed by the primary air pollution control system (APCS). The primary APCS for the SITE demonstration consisted of the venturi scrubber followed by a packed-column scrubber and fabric-filter baghouse. The scrubber system removes most of the coarse particulate and any acid gas, such as hydrochloric acid in the flue gas. Following the scrubber system, the flue gas is reheated to about 250 °F by a 100-kilowatt (kW) electric duct heater, then passes through the fabric filter baghouse. The baghouse removes most of the remaining flue gas particulate. Reheating the flue gas ensures that no moisture will condense in the baghouse and adversely affect its operation.

To assure permit compliance, a secondary, or redundant, APCS consists of a demister, an activated-carbon adsorber, and a high-efficiency particulate air filter. The backup APCS is designed to ensure that organic compound and particulate emissions to the atmosphere are negligible. The following sections discuss the main components of the RKS and its APCS.

RKS Characteristics

The rotary kiln combustion chamber has an inside diameter of 3.4 feet and is 7.4 feet long. The chamber is lined with refractory to an average thickness of 7.4 inches; the refractory is then encased in a 0.375-inch-thick steel shell. Total volume of the rotary kiln chamber, including the transfer duct, is 67.2 cubic feet. Four steel rollers support the rotary kiln barrel, which is turned by a variable-speed direct current motor coupled to a reducing-gear transmission. Rotation speed can be varied from 0.2 to 1.5 revolutions per minute.

The afterburner chamber is 3 feet in diameter and 10 feet long. The afterburner chamber wall is constructed of a 6-inch-thick layer of refractory encased in a 0.25-inch-thick carbon-steel shell. The volume of the afterburner chamber is 41.9 cubic feet.

Both the rotary kiln and afterburner are equipped with 2-million British thermal units per hour (Btu/hr) auxiliary fuel burners. Natural gas is used as the auxiliary fuel, although liquid waste or other fuels can also be fired. Typical firing rates can range from 1- to 1.5-million Btu/hr to the rotary kiln and 1.5- to 2-million Btu/hr to the afterburner.

For the SITE demonstration, Sonotech engineers retrofit the RKS with a pulse combustion system with a capacity of 0.25-million Btu/hr or roughly 15 to 20 percent of the typical heat input to the rotary kiln. The retrofit system consisted of a frequency-tunable pulse combustor, associated fuel and air flow controls, a process control system, and appropriate structural support. The tunable pulse combustor was mounted into the stationary wall at the ash pit end of the rotary kiln chamber. Operation of the afterburner was controlled independently of the rotary kiln by a separate process control loop. Fuel (consisting of natural gas) and air supply were taken from existing facility supply lines. Appropriate safety interlocks between the Sonotech system and the RKS system were also designed and installed.

Technology Applicability

The Sonotech pulse combustion system was evaluated to determine the advantages, disadvantages, and limitations of the technology. The evaluation was based on the nine criteria used for decision-making in the Superfund feasibility study process. Results are summarized in Table 1.

For the SITE demonstration, the waste feed for all test runs consisted of a composite mixture of contaminated soil, sludge, and tar from two abandoned manufactured gas plant (MGP) Superfund sites, one a coal-MGP, and the other an oil-MGP. One component of the waste feed consisted of a combination of pulverized coal and contaminated coal-tar sludge from the Peoples Natural Gas Company Superfund site in Dubuque, Iowa. The other components of the waste feed material were obtained from an MGP site in the southeastern United States; these components consisted of contaminated soil borings and tar waste from an oil gasification process. The mixed waste feed had a nominal heating value of 8,500 British thermal units per pound of waste (Btu/lb).

Materials-handling requirements and site-support requirements are identical to those of the incinerator operating without the Sonotech system in place.

For the SITE demonstration, the technology was evaluated on its ability to destroy volatile and semivolatile organic compounds. Sonotech claims its system can also be applied to the incineration of pesticides, polychlorinated biphenyls, and dioxins and furans. In addition, Sonotech claims that the technology can be applied to processes such as drying, calcining, and heating.

The Sonotech combustor can be incorporated into the construction of most new combustion devices or can be retrofit to many existing systems ranging in thermal capacity from 250,000 Btu/hr to 200 million Btu/hr. The Sonotech pulse combustion system can be used to treat any material typically treated in a conventional incinerator, and Sonotech believes the technology is ready to be used for the full-scale incineration of hazardous, municipal, or medical wastes. For most applications, the Sonotech system can be transported in a medium-duty truck.

Technology Limitations

The Sonotech pulse combustion system can be used to treat any material typically treated in a conventional incinerator with few limitations. The system typically operates at one of the several resonant frequencies in the range of 100 to 500 cycles per second (Hertz). The system relies on this frequency to excite large amplitude pulsations in the incineration chamber. While it is possible that improper application of sound pulsations may present structural problems, Sonotech claims that its system is designed to avoid such problems. Inside the pulse combustor, the sound pressure does not exceed 1 pound per square inch or 168 decibels (dB). No structural damage to the RKS was observed during the demonstration. Outside the burner system, noise is typically in the 95- to 100-dB range. In the typical work environment of an incinerator, the noise may be sufficiently loud to be of concern. Sonotech can enclose the system to reduce the noise intensity, or the entire incinerator can be remotely located or enclosed to reduce the noise. In most applications, Sonotech believes that the loud noise will be a minor concern.

Process Residuals

An incinerator configured with the Sonotech pulse combustion system will generate the same types of residuals as an incinerator without the system, primarily incinerator ash and stack gases. Treatment residuals of kiln ash, baghouse ash, and scrubber liquor will require proper treatment and disposal. In addition, the demonstration results indicate that the heating value of the incinerator ash was reduced when the Sonotech system was used.

Site Requirements

Site requirements for an incinerator equipped with the Sonotech pulse combustion system would be nearly identical to those of an incinerator without the system. The Sonotech system requires an additional area of about 4 feet by 10 feet on one side of the incinerator, where the system can be mounted. A port into the combustion chamber is also needed to place the internal portion of the Sonotech burner. The Sonotech system requires an additional air and natural gas line, but it requires only a nominal amount of additional electricity. Depending on the application and location, sound control may be necessary when the Sonotech system is used; this sound control may consist of insulation around the unit, isolation of the incinerator, or possibly use of a sound-suppression system.

Table 1: *Feasibility Study Evaluation Criteria for the Sonotech Technology*

CRITERION	SONOTECH TECHNOLOGY PERFORMANCE
1 Overall Protection of Human Health and the Environment	The pulse combustion system technology, used with a conventional combustion chamber, destroys organic hazardous constituents in the waste feed. Air emissions are reduced by using an air pollution control system (APCS).
2 Compliance with Federal ARARs	Compliance with chemical-, location- and action-specific applicable or relevant and appropriate requirements (ARARs) must be determined on a site-specific basis. Compliance with chemical-specific ARARs depends on the treatment efficiency of the combustion system and the chemical constituents of the waste.
3 Long-Term Effectiveness and Performance	Contaminants are permanently removed from the waste. Treatment residuals from the APCS and the kiln ash require proper off-site treatment and disposal.
4 Reduction of Toxicity, Mobility, or Volume Through Treatment	With incineration, both the toxicity and volume of the waste are reduced with the destruction of organic components of the waste. With the Sonotech system, the distribution and TCLP leachability of metals were unaffected in the kiln ash, but barium and chromium concentrations were slightly lower in the scrubber liquor and higher in the baghouse exit flue gas.
5 Short-Term Effectiveness	The Sonotech system reduces the time requirement for treatment by increasing the feedrate of a conventional combustion system. Short-term risks to workers, the community, and the environment are presented during waste handling activities and from potential exposures to flue gas emissions. Adverse impacts from both can be mitigated with proper controls and procedures. Short-term risks should be similar to those from conventional combustion.
6 Implementability	The Sonotech system can be easily incorporated into new incinerator systems and can be retrofit to most existing incinerators. In addition, the system can be used to treat any material typically treated in a conventional incinerator.
7 Cost	Capital costs for equipment and installation are estimated to be in the range of $65,000 to $75,000, and annual operation and maintenance costs are estimated to be $2,500 for a full-scale incinerator.
8 State Acceptance	State acceptance is anticipated to be favorable because the system can be used as a retrofit to an existing permitted hazardous waste incinerator to improve the performance of conventional combustion technology.
9 Community Acceptance	The minimal short-term risks presented to the community along with the permanent removal of hazardous waste constituents and the improved performance of a permitted waste combustion unit should make public acceptance of this technology more probable.

Materials-handling requirements for an incinerator are not affected by the Sonotech pulse combustion system; however, the Sonotech system may require an increased feedrate to the incinerator.

Performance Data

To achieve the demonstration objectives, tests were performed in triplicate at four different incineration system operating conditions, for a total of 12 individual tests. The four test conditions included (1) conventional combustion at typical operating conditions; (2) conventional combustion at its maximum feedrate, which approaches permit noncompliance; (3) Sonotech pulse combustion at the conventional combustion maximum feedrate (the same nominal feedrate as condition 2); and (4) Sonotech pulse combustion at its maximum feedrate. A summary of the operating data and results is presented in Table 2. As shown in this table, the kiln exit gas temperature was approximately 1,700 °F while the afterburner exit gas temperature was 2,000 °F. The results of preliminary testing with the Sonotech system operating showed that the rotary kiln gas temperature had to be limited to 1,700 °F to prevent slag formation, while the afterburner could be maintained at a typical operating temperature of 2,000 °F. Results of the test program in terms of the primary objectives are summarized below.

Incinerator Capacity

The Sonotech pulse combustion system increased the incinerator waste feedrate capacity by 13 to 21 percent compared to conventional combustion. As the demonstration waste had significant heat content, the capacity increase was equivalent to a reduction in the auxiliary fuel needed to treat a unit mass of waste from 27,400 Btu/lb for conventional combustion to 21,500 Btu/lb for the Sonotech system. Visual observations indicated improved mixing in the incinerator cavity with the Sonotech system operating.

Destruction and Removal Efficiency

DRE is the measure of organic constituent destruction and removal during the test program; POHCs for this demonstration included benzene and naphthalene. The POHC DREs were calculated from the concentrations of benzene and naphthalene in the flue gas emissions and their respective feedrates, as follows.

$$\text{DRE} = \left(1 - \frac{\textit{emission rate}}{\textit{feedrate}}\right) \times 100$$

Benzene DREs for all 12 test runs were greater than 99.994 percent, with a slight improvement in the third decimal place for the Sonotech combustor results. With the Sonotech pulse combustion system operating, the average benzene emission rate was reduced from 7.7 to 5.7 milligrams per hour (mg/hr) at the afterburner exit. This represents a 26 percent reduction. The quantitation of benzene at these low emission rates is within the precision of this type of measurement.

Naphthalene DREs were greater than or equal to 99.998 percent for all test runs. With the Sonotech pulse combustion system operating, the average naphthalene emission rate was reduced from 1.2 to 1.1 mg/hr at the afterburner exit. This represents an 8 percent reduction, although again, the quantitation of naphthalene at these low emission rates is within the precision of this type of measurement.

For every test, concentrations of all organic constituents were below their respective analytical method detection limits in the kiln bottom ash, indicating that the waste feed was essentially decontaminated of organics for all 12 test runs.

Carbon Monoxide and Nitrogen Oxides Emissions

The average afterburner exit carbon monoxide concentration, corrected to 7 percent oxygen, decreased from 20 parts per million (ppm) with conventional combustion to 14 ppm with the Sonotech system. This represents a 30 percent reduction.

The average afterburner exit nitrogen oxides concentration, corrected to 7 percent oxygen, decreased from 82 ppm with conventional combustion to 77 ppm with the Sonotech system. This represents a 6 percent reduction.

Soot Emissions

Flue gas soot was measured by analyzing the carbon content of the afterburner exit flue gas particulates. Average afterburner exit soot emissions, corrected to 7 percent oxygen, were reduced from 1.9 milligrams per dry standard cubic meter (mg/dscm) for conventional combustion to less than 1.0 mg/dscm with the Sonotech system. This represents a 47 percent or greater decrease in soot. However, all soot measurements were within a factor of 3 of the method detection limit, so the significance of this reduction is uncertain.

Combustion Air Requirements

One of Sonotech's claims about the technology was that pulsations would induce better gas phase mixing, resulting in more efficient combustion and reduced combustion air

Table 2: Operating Data and Results

Parameter	1: Conventional Combustion Baseline Feedrate	2: Conventional Combustion Maximum Feedrate	3: Pulse Combustion Baseline Feedrate	4: Pulse Combustion Maximum Feedrate
Waste feedrate, lb/hr	61.0	72.8	73.6	82.4
Rotary kiln exit gas temperature, °F	1,720	1,730	1,700	1,700
Afterburner exit gas temperature, °F	2,000	2,000	2,000	2,000
Heat input, kBtu/hr				
Waste feed	522	601	628	697
Kiln auxiliary fuel				
Main burner	656	516	487	403
Sonotech burner	0	0	200	200
Total kiln	656	516	687	603
Afterburner auxiliary fuel	1,010	1,020	894	882
Total auxiliary fuel	1,670	1,540	1,580	1,480
Total system heat input	2,190	2,140	2,210	2,180
Kiln ash heating value, Btu/lb	1,240	1,320	<500	1,410
Combustion air, dscf/hr	41,700	39,500	35,700	38,400
Afterburner exit CO, ppm at 7% O_2	15	20	14	17
Afterburner exit NO_x, ppm at 7% O_2	90	82	77	78
Afterburner soot emission rate mg/dscm at 7% O_2	<1.3	1.9	<1.0	1.3

Notes: Each value (except condition 1 afterburner soot emissions) is the average of results for three test runs.

lb/hr = Pounds per hour
kBtu/hr = Thousand British thermal units per hour
Btu/lb = British thermal units per pound
dscf/hr = Dry standard cubic feet per hour
mg/dscm = Millgram per dry standard cubic meter
CO = Carbon monoxide
NO_x = Nitrogen oxides
O_2 = Oxygen
ppm = Parts per million

requirements. Combustion air is defined as the total air entering the system (burner supplied air plus system inleakages). Total system combustion air requirements, estimated from stoichiometric calculations, were 5 percent lower with the Sonotech system in operation.

Auxiliary Fuel Usage

Natural gas was used as the auxiliary fuel to maintain the rotary kiln and afterburner temperatures. As shown in Table 2, natural gas was supplied to both the main and the Sonotech burners in the rotary kiln. In order to achieve the target kiln exit gas temperature of 1,700 °F, a net heat release rate of 1.0 to 1.2 million Btu/hr was needed. Typically, to maintain an afterburner exit gas temperature of 2,000 °F, an additional 1-million Btu/hr heat release rate was required in the afterburner. The average system total natural gas usage from test to test was nearly equal. The total system (kiln and afterburner) average natural gas usage was 1,580 dry standard cubic feet per hour (dscf/hr) for conventional combustion and 1,540 dscf/hr for the Sonotech system.

Other Demonstration Results

Results of the test program in terms of the secondary and other test objectives are summarized as follows:

- The frequency of transient carbon monoxide puffs, as measured at the afterburner exit, was slightly reduced when the Sonotech pulse combustor was used.

- The concentration of TUHC in the afterburner exit flue gas was near the analytical detection limit. Run-to-run and test-condition-to-test-condition differences were minimal.

- Target metals investigated included antimony, barium, beryllium, cadmium, chromium, and lead. These metals were present at low concentrations in the feed material. They were also present at low concentrations in the kiln ash, scrubber liquor, and baghouse exit flue gas. Their distribution in the kiln ash discharge did not vary significantly from test to test or from test condition to test condition. Concentrations of barium and chromium in the scrubber liquor were slightly lower and in the baghouse exit flue gas were higher with the Sonotech system operating.

- Concentrations of target metals in the TCLP leachates were low to not detected in the feed, kiln ash, and scrubber liquor. At these concentrations, no significant test-to-test variations in the TCLP leachability of the various discharge streams were observed.

- The baghouse exit flue gas was sampled for polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). No PCDD and PCDF emissions were detected.

- The RKS stack was sampled to measure hydrogen chloride and particulate emissions for all 12 tests. These measurements were performed to meet the IRF operating permit requirements. Stack particulate loading ranged from less than 0.5 to 2 milligrams per dry standard cubic meter (mg/dscm) at 7 percent oxygen for the 12 tests and were considerably lower than the maximum permit-allowed 180 mg/dscm. Furthermore, there were no variations in the particulate loading between the different test conditions. Hydrogen chloride was not detected in the flue gas emissions from any test. The hydrogen chloride detection limit corresponds to an emission rate of 0.2 g/hr.

- The kiln ash was analyzed to determine its heating value. As shown in Table 2, the heating value of the residual kiln ash was reduced by greater than 64 percent with the Sonotech pulse combustor operating.

- Under the demonstration test conditions, the Sonotech system can produce a cost savings due to increased incinerator capacity. According to Sonotech, the cost of a Sonotech pulse combustion system, retrofit to an existing full-scale incinerator, ranges from $60,000 to 70,000, depending on the application. The estimated installation cost is $5,000, and the cost of maintenance (including parts replacement, preventive maintenance, and labor) is about $2,500 per year. During the Sonotech demonstration, the Sonotech combustion system caused no downtime and was judged to be reliable.

Technology Status

The Sonotech technology has been tested under various conditions, and it is currently commercially available for a number of applications. According to Sonotech, Cello® systems have been installed and operated at (1) Holnam Cement Plant in La Porte, Colorado, where a pre-calciner was retrofit with Sonotech's pulse combustion system, and (2) at a confidential industrial location in California. A field test of the Sonotech system was conducted at Atlantic Steel facility in Cartersville, Georgia. Sonotech plans to install and operate a Sonotech pulse system at the Blue Circle Cement plant in Atlanta in July 1995. Results from these tests are available from Sonotech.

Conversion Factors

	English (US)	x	Factor	=	Metric
Length:	1 inch	x	2.54	=	centimeter (cm)
	1 foot	x	0.305	=	meter (m)
Volume:	1 gallon	x	3.78	=	liter (L)
	1 cubic foot	x	0.0283	=	cubic meter (m^3)
Mass:	1 grain (gr)	x	64.8	=	milligram (mg)
	1 pound (lb)	x	0.454	=	kilogram (kg)
	1 ton (t)	x	907	=	kilogram (kg)
Energy:	1 British thermal unit (Btu)	x	1.05	=	kilojoule (kj)
	1 million British thermal units per hour (Btu/hr)	x	290	=	kilowatts (kW)
Temperature:	(°Fahrenheit (°F) - 32)	x	0.556	=	°Celsius (°C)

Disclaimer

The data and conclusions presented in this Technology Capsule are preliminary and have not been reviewed by the EPA Quality Assurance Office.

Sources of Further Information

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