

EXPERIENCE WITH AIR POLLUTION CONTROL EQUIPMENT AND CONTINUOUS MONITORING INSTRUMENTATION ON HAZARDOUS WASTE INCINERATORS*

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Summary

The United States currently generates more than 300 million tons of hazardous waste annually. More than three million tons are currently burned, 60% at incinerators located on the site where the wastes are generated, 15% at off-site, commercial incinerators, and 25% in boilers and industrial furnaces, such as cement kilns. The U.S. Environmental Protection Agency (EPA) recently estimated that nearly seven million tons of organic sludges and liquids, as well as unknown amount of inorganic sludges, liquids and solids can be routinely incinerated. This would require more than doubling total existing incineration capacity. The potential of incineration is clearly evident. Liability considerations and landfill bans under the Resource Conservation and Recovery Act (RCRA) provide further motivation.

If waste incineration is to achieve its potential, it is essential that efficient, reliable air pollution control equipment be available. It is also essential that accurate, reliable instrumentation be available to continuously monitor stack emissions and assure proper incinerator operation at all times. This paper will review and evaluate current experience with air pollution control equipment and continuous emission monitoring instrumentation installed on hazardous waste incinerators.

Introduction

One of today's major environmental issues is the proper disposal of hazardous waste. Of all the terminal treatment technologies, properly designed incineration systems are capable of achieving the highest overall degree of destruction and control for the broadest range of hazardous waste streams. Over the past twenty years, significant advances have been made in incineration technology, particularly in the air pollution control systems developed to meet the more and more stringent regulations. The same is true for continuous emission monitors (CEM). The regulatory requirement to automatically cut off waste feed if certain continuously monitored emissions are exceeded, necessitates that CEM instrumentation be accurate and reliable. The current state-of-the-

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art of air pollution control systems and continuous stack emission monitors will be reviewed following a brief discussion of contaminants in the flue gas stream.

Flue gas contaminants

The types and concentrations of contaminants in the flue gases of hazardous waste incinerators depend on incinerator type, the waste being burned and combustion conditions. Flue gas contaminants are generally categorized as follows:

- Particulate matter,
- Acid gases,
- Heavy metals, and
- Products of incomplete combustion (PICs).

Particulate matter consists primarily of entrained non-combustible matter in the flue gas, as well as the products of incomplete combustion that exist in solid or aerosol form (fly-ash). Uncontrolled particulate loadings in the flue gas have been found to range from 0.5 to 5 grains per dry standard cubic foot (dscf).

Acid gases are the flue gas constituents which, when combined with water or water vapor, form acids including nitric oxide, nitrogen dioxide, sulfur dioxide, sulfur trioxide, hydrogen chloride and hydrogen fluoride. Hydrogen chloride and sulfur dioxide are often present in concentrations ranging from a few hundred ppmv to several thousand ppmv (parts per million by volume). The concentrations of nitrogen oxides, hydrogen fluoride and sulfur trioxide are typically below a few hundred ppmv.

Metallic compounds, such as the heavy metals Pb, Cd, As, Ni, Cu and Hg, are present in the flue gas primarily as oxides and chloride salts. Most of the metallic compounds are in the vapor phase within the incineration system, since these compounds boil or sublime at temperatures around 1800 °F (~ 1000 °C). The metallic compounds tend to condense as the flue gas is cooled and become adsorbed onto fine particulate matter (generally submicron in size). It is possible that a portion of the more volatile metals such as mercury and lead may remain in the vapor phase, depending upon temperature conditions.

Products of incomplete combustion include carbon monoxide and trace organics. Organic emissions are highly dependent upon constituents in the waste feed and combustion conditions. Depending upon the temperature, some of the organic constituents will also condense on fine particulates as with the heavy metals.

Air pollution control systems

Air pollution control systems for hazardous waste incinerators traditionally have been characterized as either wet or dry systems. Wet systems generally

utilize either venturi-type scrubbers (conventional, collision-type or ejector-type), wet electrostatic precipitators, or Ionizing Wet Scrubbers (Ceilcote) for particulate control, and packed towers for acid gas control. Dry systems generally utilize either fabric filters or electrostatic precipitators for particulate control and spray reactors for acid gas control. Representative wet dry and scrubbing facilities are identified in Table 1.

Representative facilities using either wet scrubbers, fabric filters or electrostatic precipitators for particulate control along with the expected performance for each type of equipment are identified in Tables 2–9. A comparison of fabric filters versus electrostatic precipitators for particulate removal in dry systems is presented in Table 10. A comparison of wet versus dry scrubbing systems is presented in Table 11.

Recently, hybrid systems (wet–dry) have come onto the market claiming to achieve the highest possible acid-gas removal efficiency and the lowest possible particulate emission rate. A hybrid system, for example, has recently been proposed for a commercial hazardous waste disposal company in Massachusetts. The system includes a spray dryer for evaporation and some gas absorption, a

TABLE 1

Representative wet and dry scrubbing hazardous waste incineration facilities

Wet facilities

Rollins - Deerpark, TX; Baton Rouge, LA; Bridgeport, NJ
 CWM - Chicago, IL; Port Arthur, TX; Sauget, IL (unit No. 1)
 ENSCO, El Dorado, AK
 Pyrochem, Coffeyville, KS
 GE - Waterford, NY; Pittsfield, MA
 Chem-Security, Swan Hills, Alberta, Canada
 Dow Chemical - Freeport, TX; Midland, MI; Plaquemine, LA
 Robert Ross and Sons, Grafton, OH
 3M Chemolite, St. Paul, MN
 McDonald Douglas, St. Louis, MO
 Kodak, Rochester, NY
 L.W.D. Calvert City, KY
 DuPont - Deepwater, NJ; LaPlace, LA
 Ciba Geigy, McIntosh, AL
 BASF, Geismar, LA

Dry facilities

Kommunekemi, Nyborg, Denmark
 Sakab, Norrortorp, Sweden
 Ongelmajate, Riihimake, Finland
 Tricil Ltd., Sarnia, Ontario, Canada
 Calgon Corporation, Cattlesburgh, KY
 Trade Waste Incineration, Sauget, IL (unit No. 2)
 Tredi Gerep, Mitry Mory, France

TABLE 2

Representative hazardous waste incineration facilities with Venturi-type wet scrubbing systems for particulate removal

Ventun-type wet scrubbing systems

Conventional

CWM-Trade Waste, Sauget, IL, Unit No. 1 (40-50 in. W.C. pressure drop venturi)

Eli Lilly, Ireland (70 in. W.C. pressure drop venturi)

Collision (Calvert Environmental)

Rollins Deer Park, TX (45-50 in. W.C. Pressure drop venturi)

Rollins, Bridgeport, NJ (45-50 in. W.C. pressure drop venturi)

Ejector venturi (Hydro-Sonics)

ENSCO, El Dorado, AK (steam injection, no fan, 100 in. W.C. pressure drop equivalent)

Texas Eastman, Longview, TX (Tandom nozzle, water injection, fan drive, 36 in. W.C. pressure drop on gas side)

TABLE 3

Particulate removal performance of Venturi-type wet scrubbing systems

Pressure drop, in. W.C.*	Outlet gr/dscf ^b corrected to 7 vol.% O ₂
30-40	0.06 -0.08
40-50	0.03 -0.05
50-70	0.02 -0.03
70-100	0.015-0.02

*in. W.C. is pressure drop measured in inches water column.

^bgr/dscf is grains per dry standard cubic feet.

TABLE 4

Representative hazardous waste incineration facilities with Ionizing wet scrubbing systems for particulate removal

Ionizing wet scrubbing systems

Rollins, Baton Rouge, LA

Pyrochem, Coffeyville, KS

SCA, Chicago, IL

CWM, Port Arthur, TX

Oak Ridge Gaseous Diffusion plant, Oak Ridge, TN

GE, Waterford, NY

GE, Pittsfield, MA

Government of Alberta-Bow Valley, Swan Hills, Alberta, Canada

Robert Ross and Sons, Grafton, OH

TABLE 5

Particulate removal performance of Ionizing wet scrubbing systems

No. of stages	Outlet gr/dscf corrected to 7 vol.% O ₂
1	0.07 -0.08
2	0.05 -0.07
3	0.03 -0.05

TABLE 6

Representative hazardous waste incineration facilities with Electrostatic precipitator systems for particulate removal

Electrostatic precipitator systems

Kommunekemi, Nyborg, Denmark (2-field)
 Sakab, Norrtoorp, Sweden (3-field)
 PPG, Circleville, OH (3-field)

TABLE 7

Particulate removal performance of Electrostatic precipitator systems

No. of fields	Outlet gr/dscf corrected to 7 vol.% O ₂
3	0.01 -0.015
4	0.008-0.01

TABLE 8

Representative hazardous waste incineration facilities with Fabric filter systems

Fabric filter systems

Ongelmajate, Riihimaki, Finland
 Tricil, Sarnia, Ontario, Canada
 CWM-Trade Waste, Sauget, IL, unit No. 2
 Calgon, Big Sandy Plant, Cattlesburg, KY
 General Motors, Oshawa, Ontario, Canada
 Marine Shale Processors, Amelia, LA
 Tredi Gerep, Mitry Mory, France

TABLE 9

Particulate removal performance of Fabric filter systems

Bag type	Outlet gr/dscf corrected to 7 vol.% O ₂
Fiberglass bags with acid-resistant coating	0.007-0.015
Goretex bags [®]	0.004-0.008

TABLE 10

Fabric filters vs. electrostatic precipitators

Criterion	Fabric filter	ESP
Total particulate removal	Higher	Adequate
Fine particulate removal	Better	Adequate
Relative sensitivity to particulate characteristics	No	Yes
Contribution to acid-gas removal capability	Yes	No
On-line maintenance capability	Yes	No
Reliability	Adequate	Higher
Flue gas temperature limitations	Yes	No

TABLE 11

Wet vs. dry scrubbing

Criterion	Wet	Dry
HCl removal	Better	Adequate
Sulfur oxide removal	Better	Adequate
Particulate removal	Adequate	Significantly better
Condensed metal (fine particulate) removal	More condensation, less efficient fine particulate removal	Less condensation, more efficient fine particulate removal
Volatile metal (e.g., mercury, lead, phosphorous) removal	Better	Adequate
Waste disposal requirements	Wastewater blow down	Dry solids
Stack plume	Visible	Relatively clear
Flue gas reheat	May be required	Not required
Corrosion potential	Higher	Lower
Sorbent reagent costs	Lower	Higher
Space requirements	Lower	Higher

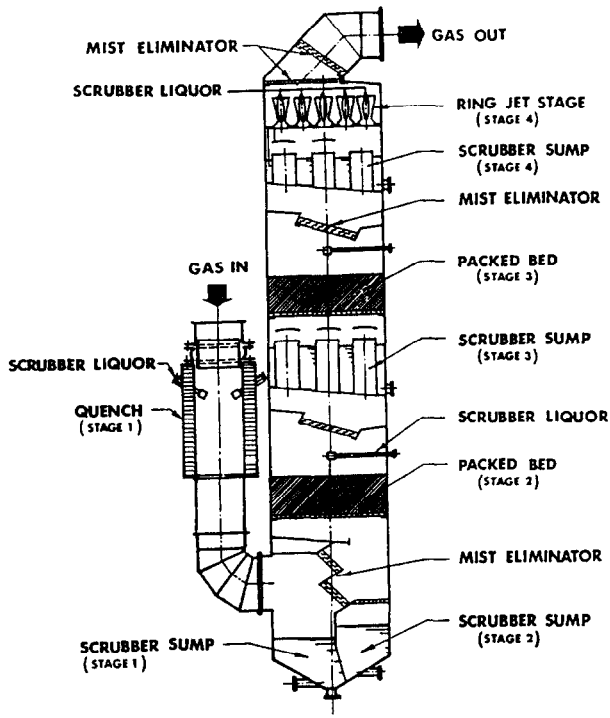


Fig. 1. Typical four-stage hazardous waste incineration scrubbing system.

fabric filter for particulate removal (and some additional gas absorption), and a multi-staged gas scrubber (refer to Fig. 1). The multi-staged gas scrubber consists of a quench section (stage 1), followed by two packed beds (stages 2 and 3) for final acid gas removal and a multiple venturi ring jet fourth stage to remove any remaining particulate matter, including any which condenses at the lower wet scrubber temperature. The venturi scrubber backup system also provides insurance protection in the event of bag breakage in the fabric filter. There is no liquid blowdown from this hybrid system. Blowdown from the wet scrubber system is sent to the spray dryer for liquid evaporation. The planned incineration facility will also use ammonia injection for nitrogen oxides control.

Continuous emission monitoring

Although incineration has proven to be effective and reliable over a very wide operating envelope, there is need for continuous stack monitoring to ensure that the operation remains within the acceptable operating envelope at all times. The existence of such continuous emission monitoring (CEM) equipment also increases public confidence in the operation.

While the interpretation of certain monitored stack parameters on hazardous waste incinerators presents problems (as will be discussed later), most of the CEM instrumentation does a reasonably good job from an accuracy and reliability standpoint under the circumstances. Carbon monoxide and carbon dioxide measurement by NDIR (Non-Dispersive Infrared) is generally accepted as reliable, so long as emissions are properly preconditioned. Oxygen can also be measured accurately and reliably in the flue gas using a zirconium oxide ceramic sensing element which when hot becomes an electrolytic conductor, although it may take some trial-and-error to identify the "right" location.

The accuracy and reliability of nitrogen oxides (via a chemiluminescence monitor) and sulfur dioxide (via flame photometry or pulsed fluorescence) CEM instrumentation has also been demonstrated. Opacity CEM instrumentation is in the same category.

While it has not been traditional to require HCl CEM instrumentation on hazardous waste incinerators, this is now becoming more the norm as a result of public pressure and participation in the permitting process. Unfortunately, experience with such instrumentation on municipal solid waste (MSW) incinerators has been less than satisfactory, particularly due to HCl reactions with particulate and sampling system surface areas, and metal degradation due to HCl corrosivity. These problems appear to have been overcome by a relatively new HCl monitoring system manufactured by Bodenseewerk Gerätetechnik GmbH, a division of Perkin Elmer [1]. Flue gas is drawn out of the stack through a coarse (sintered stainless steel) filter with pores of approximately 50 μm diameter. The filter is capable of being backpurged periodically. This blowback feature alleviates filter blockage and avoids measurement errors that could occur due to the HCl reacting with particulate deposits in the filter surface. The entire sampling system is maintained at 200°C which does not allow the HCl to react with the surface areas in the sampling system. A heated pump maintains sample flow rate at approximately 10 l/min. Like sample temperature, sample flow rate was found by Bodenseewerk to have an effect on maintaining the integrity of the HCl concentration, e.g., flow rates less than 10 l/min showed an increased tendency of the HCl to absorb on material surfaces. Sample gas exits the flowmeter and enters a heated (200°C) detector cell for infrared analysis of HCl. The current U.S. configuration of the Bodenseewerk HCl monitoring system is designed to automatically perform a zero calibration and a span check on a daily basis. The total time for such checking is 20–30 min.

While CEM instrumentation has come a long way over the last twenty years, the interpretation of certain data still leaves much to be desired. The use of CO and THC (total hydrocarbon) data, for example, have been presumed as incinerator performance, i.e., destruction efficiency, indicators. Unfortu-

nately, the situation has been found to be much more complex than first thought.

There are two general classes of incinerator performance indicators. The first of these involves the use of compounds which are either identified in the waste or added to it (such as freons or sulfur hexafluoride) to serve as "surrogates" for the destruction of other important compounds in this waste. The second approach involves the use of indicator emissions such as CO or unburned hydrocarbons (THC) to mirror waste destruction efficiency.

Unfortunately, there has been little data collected to indicate that CO or THC correlates with destruction efficiency of POHCs (principal organic hazardous constituents). Furthermore, there has been little data presented to indicate that CO correlates with PIC emissions [2]. Currently, CO is generally considered to be too sensitive to variations in incinerator operating conditions, i.e., CO will rise significantly before flue-gas organic levels rise [3].

A difficulty with THC is that it is waste specific. Since a total hydrocarbon monitor (e.g., flame or photo-ionization detector) responds by its design to basically carbon-hydrogen bonds, one can defeat the purpose of the monitor by increasing the chlorine content of the waste. Thus one would have a situation where potentially more toxic chlorinated products are being produced from combustion of the waste while response of the monitor decreases because of the increasing number of carbon-chlorine bonds at the expense of the number of carbon-hydrogen bonds. An additional problem is that THC monitors only respond to species containing six carbons or less due to lack of transport of higher molecular weight compounds through the sampling lines [2].

The use of ratios such as the CO/CO₂ mole ratio or the total unburned hydrocarbons to carbon dioxide mole ratio have been shown in pilot testing to correlate generally with POHC destruction efficiency [4]. Unfortunately, attempts to correlate field data have been inconclusive to date.

The use of additives such as various freons and sulfur hexafluoride have been studied in the laboratory [5]. Unfortunately, many of the compounds thus far proposed are not strictly representative of the incinerability of the actual waste. Moreover, surrogate destruction may not correlate with PIC emissions. For example, one may be able to destroy basically any toxic organic compounds but not be able to meet the 99.99% requirement for sulfur hexafluoride due to its extreme stability [2]. Although laboratory studies indicate that a correlation exists between POHCs and sulfur hexafluoride destruction, field data suggest a more complex situation [6].

Public pressure is now placing a high priority on the development of a method capable of being continuously monitored to assure that incinerator operation remains acceptable at all times.

Conclusions

Air pollution control equipment on hazardous waste incinerators

1. Wet systems and hybrid (wet-dry) systems can meet current RCRA re-

quirements for particulate and HCl removal.

2. Dry systems are capable of achieving the lowest particulate emission rate.
3. Wet systems are capable of achieving the highest acid-gas removal efficiency.
4. Hybrid systems are capable of achieving the lowest particulate emission rate and highest acid-gas removal efficiencies.

Continuous emission monitoring equipment (CEM)

1. Carbon monoxide, carbon dioxide, oxygen, sulfur dioxide, nitrogen oxides and opacity can be measured reliably with CEM instrumentation.
2. Total hydrocarbons can be measured continuously but the response is inconclusive.
3. Hydrochloric acid CEM instrumentation has experienced reliability problems, but a new NDIR technique developed by Bodenseewerk shows considerable promise.
4. No surrogate method has yet demonstrated the capability of reliably predicting POHC destruction efficiency in the field.
5. In order to satisfy the public, there remains a need to develop a CEM instrument which can assure proper incinerator performance at all times without placing unnecessary constraints on the operation.

References

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