



## Project Summary

# Incinerator Operating Parameters Which Correlate with Performance

Laurel J. Staley, Marta K. Richards, George L. Huffman, and Daniel P. Y. Chang

A research project entitled "A Study of Incinerator Operating Parameters Which Correlate With Performance" was conducted by the Thermal Processes Research Staff of the Hazardous Waste Engineering Research Laboratory. This project evaluated how closely carbon monoxide (CO) reflected incinerator performance as measured by emission levels of unburned or incompletely burned simulated chemical waste. The results of this research are contained in a report entitled "Incinerator Operating Parameters Which Correlate With Performance."

Within this report are results of two different sets of tests; in the first set, a series of six experiments were conducted in which five different chemicals frequently found in hazardous waste streams were diluted in heptane and burned in a water-jacketed pilot-scale combustor under a series of excess air levels which span the range from fuel-rich to fuel-lean combustion. In the first five experiments, compounds were diluted with heptane and burned individually (either 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethylene, carbon tetrachloride, chlorobenzene or Freon-113). In the sixth experiment, Freon-113 and chlorobenzene were burned together to test for mixture effects. Carbon monoxide levels in the combustor exhaust were continuously monitored as was exhaust temperature. Emission levels of unburned and incompletely burned hydrocarbons were determined by sampling the combustor exhaust using Tenax-GC<sup>®</sup> filled sorbent traps which were subsequently analyzed by a gas chromatograph equipped with a Hall Detector. In the second set of tests, CO concentration and Destruction Efficiency (DE) were measured as a function of Swirl Number and

fuel nozzle position. The second set of tests was accomplished using a GC/MS (gas chromatograph/mass spectrometer) for analysis.

In general, the results of these experiments indicated that CO levels in the research combustor exhaust did not directly reflect the exhaust emissions of unburned and incompletely burned chlorinated hydrocarbon. Rather, these emissions were more directly affected by the specific nature of the chemical being burned and by the combustor operating temperature.

*This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project That is fully documented in a separate report of the same title (see project report ordering information at back).*

### Introduction

Performance standards developed under the Resource Conservation and Recovery Act require that hazardous waste incinerator operators achieve 99.99% Destruction and Removal Efficiency (DRE) on the Principal Organic Hazardous Constituents (POHCs) present in the waste streams they burn. (POHCs are generally waste chemicals designated by the permit writer on the basis of their concentration, toxicity and non-combustibility relative to the other constituents of the waste stream.) Compliance with this standard is usually determined in a trial burn in which a waste stream representative of what the incinerator would usually receive is incinerated. Extensive sampling is done at the incinerator's stack to measure POHC emission levels. These samples are analyzed to determine the level of POHC in the ex-

haust. This information, along with information on the composition of the feed, is then used to determine DRE and ultimately compliance with the RCRA incineration regulations.

Not only is this method of determining compliance time-consuming and expensive, it only provides information on the incinerator's performance during the time of the test. Since an incinerator's waste feed may vary widely in composition, it may not be valid to assume that if the incinerator is operated as it was during the trial burn, it will continue to be in compliance with the RCRA regulations regardless of variations in waste feed. Therefore, there is a need for some way to continuously monitor incinerator performance, to immediately warn the operator of the onset of performance deterioration so that corrective action can be taken before an air pollution problem results.

One method being considered involves using CO levels in the exhaust to indicate DRE. Readily available and inexpensive methods exist to monitor CO levels in incinerator exhaust. If the level of CO in the exhaust could in some way be tied to the levels of unburned POHCs in the exhaust and, ultimately, to DRE, then CO could be used as a continuous indicator of DRE which would alleviate the above-mentioned uncertainties.

The purpose of this preliminary study was to examine the usefulness of CO as an indicator of DRE under well-controlled laboratory conditions.

### Description of the Research Conducted

In the first set of tests, a series of five compounds, common constituents of waste streams and often chosen as POHCs, were burned in a water-jacketed pilot-scale research combustor under a range of excess air levels. The compounds chosen were 1,1,2,2-tetrachloroethane (TCA), 1,1,2-trichloroethylene (TCE), carbon tetrachloride (CCl<sub>4</sub>), chlorobenzene (CLBZ), and Freon-113, F113 (1,1,2-trichloro-1,2,2-trifluoroethane). Each compound was tested separately. In each run, the compound was diluted in normal heptane to produce a two-mole percent solution. In a sixth run, chlorobenzene was burned with Freon-113 (CB/F), each at 2 mole percent. For each run, the combustion air flow rate was varied while fuel flow was held constant, thus producing different excess air levels and causing the CO levels in the combustor exhaust to span the range of observable values. At five or sometimes six different sets of operating

conditions, incinerator exhaust samples were drawn through Tenax-GC<sup>®</sup> sorbent traps for purposes of determining the levels of unburned POHC being emitted from the incinerator under these various conditions. These traps were analyzed by a gas chromatograph equipped with a Hall Detector. In the second set of tests, CO concentration and DE were measured as a function of Swirl Number and fuel nozzle position. A GC/MS was used for the analyses required by the second set of tests.

The Turbulent Flame Reactor (TFR) shown in Figure 1 was the experimental combustor used for this study. Fuel entered the TFR through a Delavan pressure-atomizing nozzle located at the bottom of the reactor. Combustion air also entered

at the bottom of the TFR through an International Flame Research Foundation swirl box which was designed so that the amount of angular momentum ("swirl" imparted to the incoming air could be closely controlled. A water jacket surrounded the entire combustion chamber and removed approximately 45,000 BTU/hr from the system. All samples were taken from probes in the exhaust port.

In addition to taking Tenax-GC<sup>®</sup> trap samples, the exhaust was also continuously monitored for CO, carbon dioxide, oxygen, and Total Unburned Hydrocarbons. Non-dispersive infra-red analyzers were used to monitor CO and carbon dioxide levels. A paramagnetic analyzer was used for monitoring oxygen level and a Flamm Ionization Detector was used to monitor

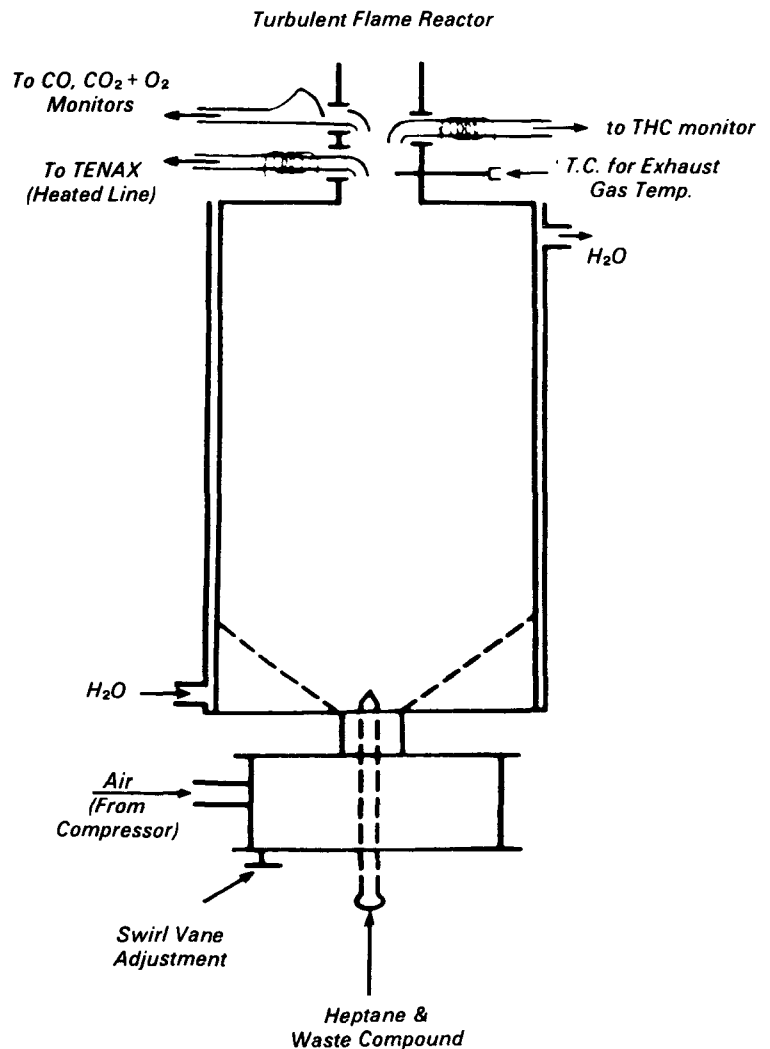


Figure 1. Turbulent Flame Reactor (TFR).

unburned hydrocarbon level. Exhaust temperature was monitored through the use of a type-K (chromel-alumel) thermocouple.

## Summary of Test Results and Recommendations

Continuous sampling for conventional measures of incinerator performance such as CO, CO<sub>2</sub>, O<sub>2</sub> and integrated sampling of POHC DE and PIC (Products of Incomplete Combustion) formation were performed under conditions of strong thermal quenching and variable levels of excess air. Preliminary studies of the effects of mixing resulting from changes in inlet air swirl and nozzle position were also carried out. A summary of the results obtained is presented below, as are recommendations for future research.

1. Over the range of excess air examined (120% < Percent Theoretical Air [%TA] < 230%), CO concentration and exhaust gas temperature were functions of the %TA in the TFR (see Figure 2 for a pictorial representation of the former). The CO functional dependence was non-linear and non-monotonic, exhibiting a minimum at about 140% TA. CO production as a function of theoretical air appeared to be relatively insensitive to the particular POHC mixed with the fuel at the

level tested, two mole percent. The behavior of CO as a function of excess air could plausibly be attributed to poor mixing leading to locally fuel-rich pockets under conditions of low excess air, and to thermal quenching under conditions of high excess air. Exhaust temperature was a monotonically decreasing function of %TA over the range tested.

2. The existence of two limbs to the CO concentrations versus %TA curve suggested correlating CO with POHC DE for one limb of the curve at a time. Adequate data were only available for the high excess air case. For the high excess air limb, POHC penetration appeared to increase as CO increased, but was dependent upon the POHC burned (see Figure 3). Qualitative agreement with the thermal stability incinerability ranking scale was observed for the POHCs: TCE, CLBZ, CCl<sub>4</sub> and TCA. Freon-113 exhibited anomalous behavior which possibly was related to an inability of the analytical method employed to distinguish Freon-113 from chloroform (a common PIC). The utility of CO as a continuous measure of POHC DE appears to be limited by the multiple-valued nature of the CO versus excess air curve as well as by dependence upon the POHC burned. Thus, it follows that the relationship between CO and DRE could be even more tenuous. Increase of CO emission did,

however, precede or occur simultaneously with the increase in POHC penetration above about 130% to 140% of theoretical air. Therefore, CO concentration might still serve as a useful upper bound for purposes of incinerator permitting, but will likely be combustor dependent. Further research investigating the low excess air limb of the curve needs to be pursued.

3. The formation of PICs was observed to increase as a function of excess air under conditions of high excess air. For an example of this, see Figure 4. The relative amounts of a given PIC formed was dependent upon the POHC burned, but numerous PICs were common to all POHCs tested. As shown in Figure 4, it was observed that a recalcitrant PIC, TCE, could be formed from a relatively easily destroyed POHC, TCA. In fact, the PIC-to-POHC ratio was observed to be greater than unity in that instance, consistent with larger pilot-scale combustor tests under similar conditions of strong thermal quenching. The potential importance of this finding applied to boilers co-firing waste is evident.

4. The common occurrence of PICs (benzene, chloromethane, dichloromethane, chloroform, carbon tetrachloride and chlorobenzene) formed from the fuel and chlorinated POHCs may contribute to an understanding of the previously found phenomena of increasing DE with increasing POHC concentration in the waste feed. POHCs which could also be formed as PICs would appear to be more difficult to destroy. The same phenomenon could be one possible explanation for the difficulties in using incinerability ranking scales to predict destruction efficiency. As a practical application of these findings, it is suggested that, for trial burns, one select recalcitrant POHCs which are not likely to be formed as PICs, but which also yield readily identifiable recalcitrant PICs as well. Further research to better understand the role of radical recombination in the formation of PICs should be pursued.

5. Hardware-related parameters such as degree of mixing produced by inlet air swirl and nozzle position were found to affect flame stability and CO emissions in preliminary testing. More comprehensive tests of the influence of such parameters on POHC DE should be carried out in the future.

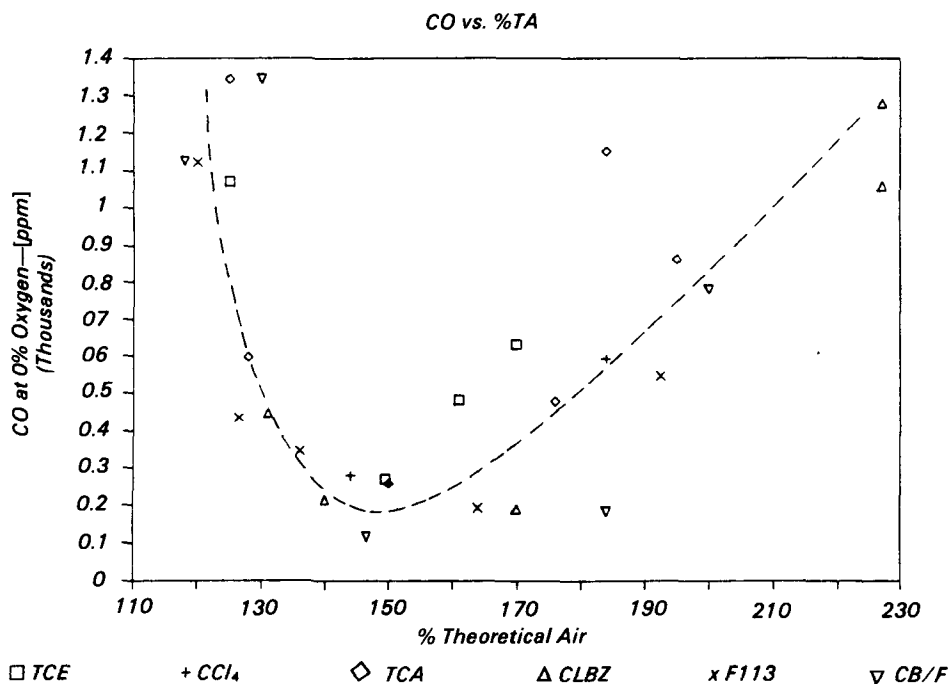
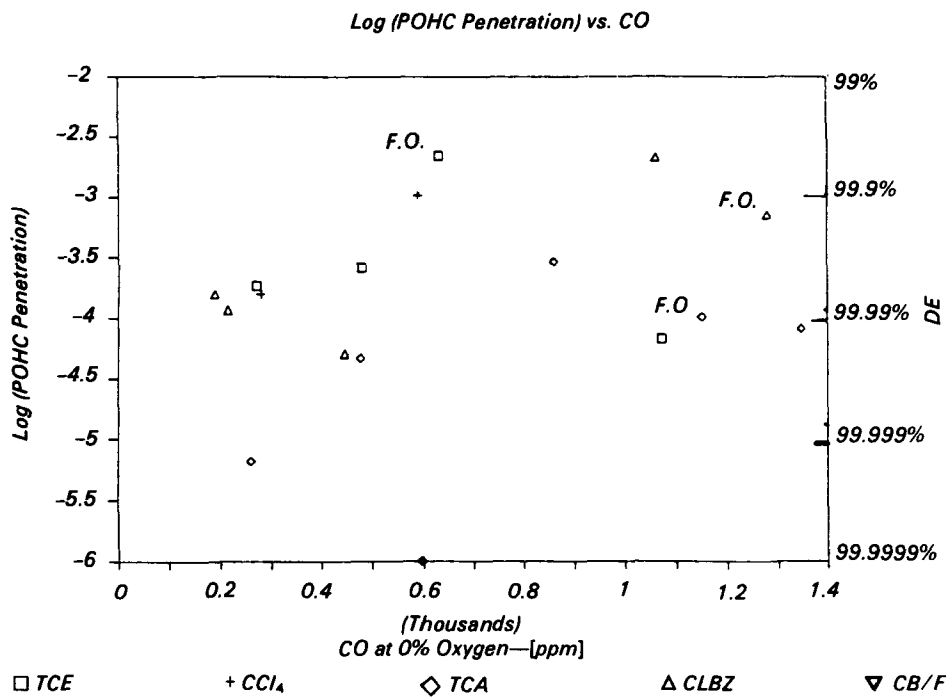
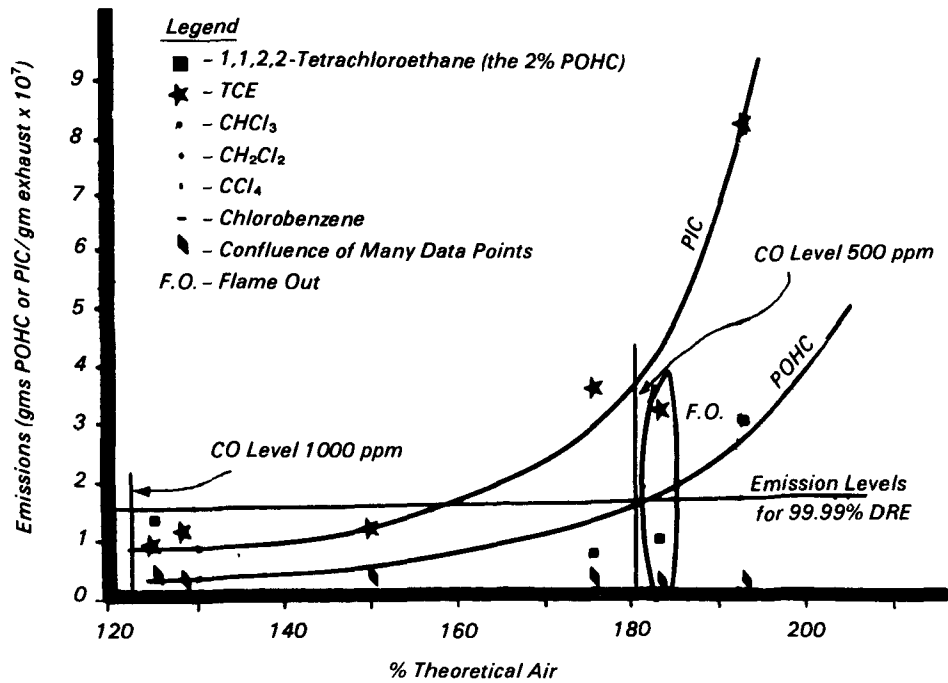


Figure 2. CO vs. % Theoretical Air (%TA): All compounds.



**Figure 3.** POHC penetration or DE vs. CO (for all compounds).



**Figure 4.** POHC and PIC emissions for the TCA burn.

OHIO 62501091

**The EPA authors Laurel J. Staley (also the EPA Project Officer, see below), Marta K. Richards, and George L. Huffman are with the Hazardous Waste Engineering Research Laboratory, Cincinnati, OH 45268; and Daniel P. Y. Chang is with the University of California, Davis, CA 95616.**

**The complete report, entitled "Incinerator Operating Parameters which Correlate with Performance," (Order No. PB 87-104 626/AS; Cost: \$9.95, subject to change) will be available only from:**

**National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
Telephone: 703-487-4650**

**The EPA Project Officer can be contacted at:  
Hazardous Waste Engineering Research Laboratory  
U.S. Environmental Protection Agency  
Cincinnati, OH 45268**

United States  
Environmental Protection  
Agency

Center for Environmental Research  
Information  
Cincinnati OH 45268

BULK RATE  
POSTAGE & FEES P  
EPA  
PERMIT No G-3E

Official Business  
Penalty for Private Use \$300  
EPA/600/S2-86/091

0000329 PS

U S ENVIR PROTECTION AGENCY  
REGION 5 LIBRARY  
230 S DEARBORN STREET  
CHICAGO IL 60604