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Hazardous Waste Engineering Research
Laboratory
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# Project Summary

# Systems Reliability and Performance: Pilot-Scale Incineration of Chlorinated Benzenes at the Combustion Research Facility

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**A series of 34 test burns was conducted between August 1983 and January 1984 in the pilot-scale rotary kiln incineration system at the USEPA Combustion Research Facility (CRF), using chlorinated benzenes as surrogate principal organic hazardous components (POHCs), over a range of feed compositions, POHC feed rates, rotary kiln temperatures, and afterburner temperatures. The CRF rotary kiln system consistently produced destruction and removal efficiency (DRE) values above 99.99% for the chlorinated benzenes POHCs. DRE values below 99.99% were obtained during several types of failure mode simulations (flame-out in kiln or afterburner). A large number of products of incomplete combustion (PICs) were produced and identified, a number of which are toxic or possibly carcinogenic. Deliberate reduction of excess air levels resulted in significant production of soot and PICs but did not produce higher levels of CO in the combustion gases. Hot-zone sampling just downstream of each of the two combustion chambers provided for the detailed study of PIC formation and will facilitate the future development of models of the incineration process. Helium injection techniques were used to determine combustion gas flow rates and to measure residence time distributions (which directly affect destruction efficiencies). This report was submitted in fulfillment of Contract 68-03-3128 by Versar, Inc. under the sponsorship of the U.S. Environmental Protection Agency.**

***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

The USEPA Combustion Research Facility (CRF) located in Jefferson, Arkansas, has as its overall mission the detailed physical and chemical study of the incineration of hazardous wastes in highly instrumented and closely controlled pilot scale incineration systems. Experimentation to date has been in a rotary kiln/afterburner system with venturi and packed-tower wet scrubbers. A liquid injection system and a stack gas carbon absorption unit are currently being installed and should be operational at the CRF by November 1984.

## *Objectives*

1. To develop methods of improving the reliability and control of the incineration process.

2. To develop relationships for predicting the performance of incinerators of varying scale and design.
3. To develop a technically defensible data base leading to additional understanding of the hazardous waste incineration process and to further the development of methods to predict the performance of incinerators as a function of key process operating variables.
4. To develop incinerator system performance data for regulated hazardous wastes to support current RCRA incinerator regulations and performance standards, and to provide additional technical basis for those future standards which may be necessary.

During the two years of activity on the CRF Program, the facility has been completed and equipped; master plans for Project QA/QC, Health and Safety, and facility operation and maintenance have been developed and implemented, as has a Master Research Plan for Fiscal Year 1984. Also, extensive modifications have been made to the rotary kiln system, and an important test burn series with simulated hazardous wastes has been completed. The RCRA Part B Hazardous Waste Incineration Permit for the CRF was recently issued by the State of Arkansas.

The CRF rotary kiln system, sampling and analytical support functions, and the supporting Health/Safety and QA/QC activities are fully operational and capable of routine operation with many types of hazardous wastes.

## *Experimental Facilities*

The CRF is housed in a 3000-square-foot concrete block building containing an incinerator room with an area of approximately 1400 square feet. The facility also contains a control room, analytical laboratories, and an instrument laboratory. Support facilities are housed in several trailers located adjacent to the CRF.

At the present time, the experimental system that is available at the CRF is a pilot-scale rotary kiln with afterburner and an air pollution control system consisting of a variable throat venturi, wetted elbow and packed tower scrubber. At present, liquid and semiliquid waste materials are fed by a positive-displacement pump through a water-cooled feed lance mounted to the front face of the kiln. A newly designed feed face, presently being fabricated, will have provisions for liquid and semiliquid feeds through a variety of lance configurations and for solids or containerized solids using a ram feed device. The new feed face will also accommodate a burner. Installation of this new equipment will take place during 1984.

Analytical capability for organics at present includes two Hewlett Packard Gas Chromatographs with Autosamplers, a High Pressure Liquid Chromatograph and associated sample preparation equipment. Hot-zone sampling is available in both the kiln and the afterburner transfer ducts to complement sampling of stack gases. Real-time monitoring of $O_2$, CO and $CO_2$ levels is provided by an automated system. The EPA Method 5, Modified Method 5 (using cooled XAD-2 resin collection medium), and the volatile organics sampling train (VOST) are routinely used for organic sampling. An on-line total hydrocarbon analyzer will be installed in the immediate future.

## *Experimental Results, Energy and Material Balance*

Material balance and the heat balance data from some early test burns are given in tabular form in the final report. Some of the pertinent results from analysis and interpretation of engineering test data from those early burns are summarized below:

- Data from 20 runs for 14 continuous measurements provide a measure of how closely steady-state test conditions were maintained during the test burns. Except for the kiln pressure (a small negative value), the relative standard deviation was no greater than 7.5 percent, showing that the system test conditions were reasonably close to steady-state.
- Three independent determinations of combustion gas flow rate showed consistent differences of up to 19 percent. The helium tracer technique has been refined to correct this inconsistency, with the development of a helium measurement system consisting of a sample loop and programmed solenoid valves, and with more frequent measurements in recognition of the true flowrate fluctuations with time introduced by the burner control systems.
- Reynolds numbers in the kiln range from 2300 to 6700, which is in the transition zone between laminar and turbulent flow regimes. Other ranges are:

| | | |
|---|---|---|
| Kiln transfer duct | $-N_{RE}$ = | 5100-14800 |
| Afterburner | $-N_{RE}$ = | 7800-13100 |
| Afterburner transfer duct | $-N_{RE}$ = | 16800-27000 |

- Heat losses and heat fluxes were calculated for major portions of the system. For example, it appears that about half of the heat input to the kiln is lost to the surroundings. For the entire system, from kiln to a point between the afterburner and scrubber, average heat losses were about 37 percent of the total system heat inputs.

## Results from Chlorinated Benzenes Test Burn Series

A system test series using hexachlorobenzene (HCB) and 1,2,4-trichlorobenzene (TCB) as surrogate hazardous waste materials was initiated in August 1983 to demonstrate the following objectives:

- Stable operation of each subsystem and of the complete integrated system, for extended testing times.
- Independent control of operating conditions for each test in accordance with the predetermined test plan.
- Acquisition and analysis of system reliability and engineering test data.
- Acquisition and analysis of exhaust stack analytical data on HCB and TCB as surrogate POHCs at a precision more than sufficient to determine Destruction and Removal Efficiency (DRE) to 99.999%.
- Development of preliminary information on pic measurement methods and identification of potential PICs from HCB and TCB.

A total of 34 test burns of 8 to 10 hours duration were performed beginning with final engineering checkout runs in August 1983 and ending on 26 January, 1984. In addition to test burns over a range of feed compositions, POHC feed rates, rotary kiln temperatures, and afterburner temperatures, tests were run in which various hot-zone sampling methods were evaluated, combustion failure modes were simulated, and test methods for residence time distribution were performed.

This test series produced data necessary to determine the DRE for POHCs across the entire rotary kiln incineration system, the Destruction Efficiency (DE) for each of the two combustion chambers, and the partial identification and quantification of PICs. The measurements for

these determinations included the characterization of the waste feed material, quantification of the waste material feed rate, the chemical analysis of time-integrated samples (at known sampling rates) taken from the stack and from hot zones downstream from each combustion chamber, and the measurement of total flow rate in the stack and at each hot-zone sampling point.

The final report contains a complete summary of the input-output data and DRE values for the two POHCs, HCB and 1,2,4-TCB, in this test series. The rotary kiln system consistently produced DRE values above 99.99 percent for refractory POHCs such as chlorinated benzenes. The DRE values for 1,2,4-TCB were higher than for HCB under comparable residence time/temperature conditions.

## Conclusions

From the data, there appears to have been essentially no variation of measured DRE for either HCB or TCB with combined temperature/residence time. Over the feed rate range of 100 to 1000 gm/hr, there also was no discernable effect of feed rate on DRE. Except for excursions during startup and shutdown, carbon monoxide levels were below 1 ppm during all of these tests; thus, the CO level did not appear to depend on feed rate or temperature/residence time over the range covered.

After a test burn with either HCB or 1,2,4-TCB in the feed, POHC emissions were found during subsequent tests wherein the only feed to the kiln was propane fuel. The source of this holdup (or residue) effect during intermittent system operation is as yet undetermined, as is its significance to steady-state commercial incineration operations.

Hot-zone sampling upstream and downstream of the afterburner permitted measurement of the destruction efficiency in the afterburner, $DE_{AB}$. The analyses for POHCs in the upstream samples show that most of the thermal destruction occurred in the kiln. The results were indicative that complex chemical interactions occur in the afterburner. In the case of HCB as the POHC, for example, previously formed PICs may react to form additional HCB in the afterburner. Under some conditions, POHC output from the afterburner was greater than the POHC input to the afterburner. This could result from PIC reactions, holdup from previous burns, or a combination of these effects.

A number of PICs, notably polyaromatic hydrocarbons (PAHs) and other chlorinated benzenes, were formed in the tests with HCB/toluene or TCB/toluene feed. Agreement between GC/MS and multidetector GC identification of PICs was very good.

Analytical data from hot zone samples show that the concentrations of organic compounds found did not correlate with particulate levels, which supports the assertion that the organic molecules are in the vapor state (not strongly associated with particulates) in the hot zones.

Several tests in this series were conducted to simulate failure modes in the rotary kiln system. Flame-out of either the kiln burner or the afterburner was simulated by intentional temporary but repeated shutdown of each burner. Temporary loss of either burner did not of itself result in the system being out of compliance. Deliberate reduction of excess air levels resulted in significant production of soot and PICs but did not produce higher levels of CO in the combustion gases.

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*The complete report, entitled "Systems Reliability and Performance: Pilot-Scale Incineration of Chlorinated Benzenes at the Combusiton Research Facility," (Order No. PB 85-121 184; Cost: $20.50, 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:*
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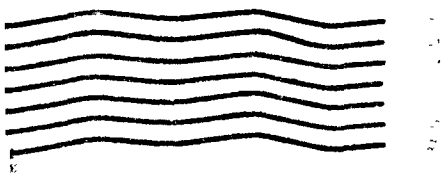


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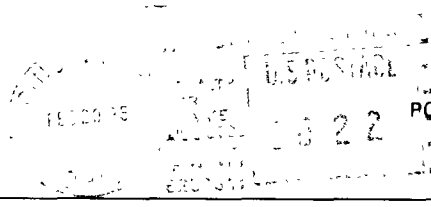

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