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Project Summary

Organic Emissions Evaluation of a Paint Bake Oven with Catalytic Incineration

Bruce C. DaRos, Richard Merrill, and William C. Kuby

This report describes sampling methods and results of a field test program conducted at the Mack Truck, Inc., paint bake oven facility located in Allentown, Pennsylvania. The purpose of the test program was to measure total hydrocarbon (THC) concentrations at the inlet and outlet of an incinerator with heat recovery used to reduce organic solvent emissions. Data were also collected to evaluate the energy efficiency and economics of the system compared to other THC control alternatives.

The incinerator system was designed by Schweitzer Industrial of Madison Heights, Wisconsin, and incorporates DuPont's Torvex catalyst with platinum to enhance hydrocarbon reduction in the process stream. The incinerator fuel is No. 2 distillate oil injected through a Model 500, combination overpack gas/oil burner manufactured by Maxon of Muncie, Indiana. The incineration system includes a heat exchanger following the catalyst bed. The gas stream being heated is circulated to the electrodeposition (E-coat) oven, thus replacing a direct heat source otherwise required. The heat exchanger "effectiveness" of this configuration was 82 percent, allowing for a recovery of 35.1 percent of total thermal energy from the gas stream.

An analysis of the annualized costs of thermal and catalytic incineration and carbon adsorption was performed. Because the concentration of hydrocarbons to the control device was small, the annualized cost of carbon adsorption was less than other control devices.

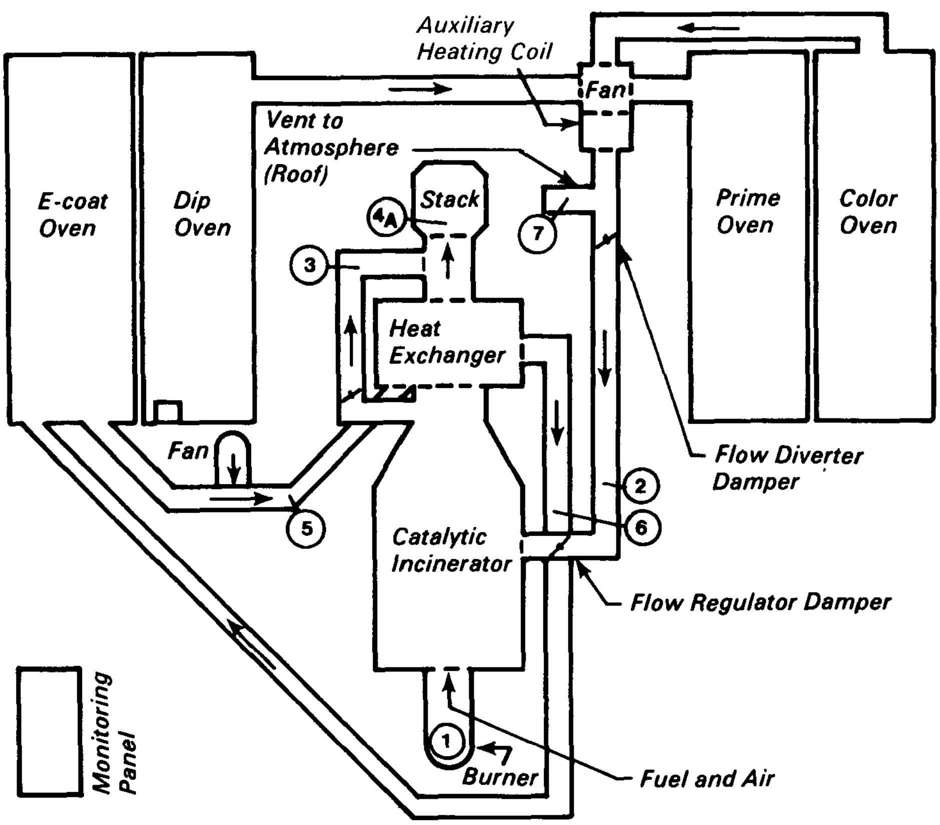
Measurements conducted at the inlet and outlet of the incinerator indicated an average reduction in organic emissions of approximately 86 percent. Bypassing the incinerator with a fraction of the total gas stream resulted in an emissions reduction to the atmosphere of 70 percent.

This Project Summary was developed by EPA's Industrial Environmental 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 painting and paint baking of new automobiles represents a major stationary source of volatile organic carbon (VOC) emissions from the transportation industry. These emissions, when destroyed efficiently, have the potential to be utilized as a fuel supplement and aid in significantly reducing the energy requirements of paint baking.

A catalytic incineration system with heat recovery and gas recirculation (Figure 1), designed to control hydrocarbon emissions from paint bake ovens,



○ **Sample Locations*

Figure 1. Schematic of the Mack Truck, Inc., incineration system.

was tested and evaluated to determine its organic solvent emissions reduction efficiency.The system incinerates off-gases from three ovens while supplying heat through a heat exchanger to a fourth oven (E-coat). The system normally operates throughout the first and second shifts, 6 days/week. A Dupont Torvex catalyst bed with platinum was installed in late 1976 to enchance the incinerator system's reduction efficiency. When this test program was conducted, less than 20 percent of the catalyst life remained (regeneration was rescheduled for 1980).

In three one-hour tests at the Mack Truck, Inc., facility in Allentown, Pennsylvania, THC concentrations were determined at the inlet and outlet of th incineration system using a Beckma Model 400 Hydrocarbon Analyzer wit a flame ionization detector. Prior t sampling, measurements were taken t determine gas phase conditions at eac test location as well as at the inlet an outlet of the heat exchanger followin the incinerator. THC concentration were recorded as equivalent methan and are summarized in Table 1. Hea exchanger performance was evaluate using mass and energy balances. Sinc the heat exchanger bypass stream join the exchanger outlet flow prior to th sampling point, actual exit condition were computed by assuming flow prop erties identical to those of air. The fol lowing balance was determined:

Fuel inflow	2.37 kg/mi
Air inflow	53.8 kg/mi
Off-gas inflow	237 kg/mi
Exchanger bypass flow	136 kg/mi
Exchanger inflow	157 kg/mi
Total outflow	255 kg/mi
Exchanger outflow	119 kg/mi

To aid in understanding the discre pancy between the computed inflov and outflow of the heat exchanger, tra versing techniques and profile result were examined at each sampling loca tion. The higher velocity profiles an flowrates were determined to be due t flow stratification. The off-gas inflow although also high, appeared sufficientl reliable to be used in the remainin computations.

The heat exchanger outlet tempera ture was not measured but compute based on the bypass, incinerator outlet and total inlet stream measurements The result was 504°K, with the unrelia bility of the exchanger bypass an incinerator outflow measurements making this a maximum value. The computed heat recovery rate was subsequently 0.740 x 10^6 joules/hr, with a total energy flowrate for the heat exchanger inlet of 2.09 x 10^6 joules/hr. Thus, 35.1 percent of the energy flux was recovered in the exchanger. To complete the energy balance, the cold-side recovery was determined to be 0.712 x 10^6 joules/hr, the difference being attributed to losses and/or data uncertainties. Using the actual heat transfer rate obtained earlier, the heat transfer effectiveness was computed to be 82 percent.

***Table 1.** Summary of Emission Rates*

Sample Location	Description	Emission Rate kg/hr (as methane)	Emission Rate ppm (as methane)
2	Paint bake oven off-gas (inlet to incinerator)	1.55	195
4	Incinerator exhaust gas (outlet of incinerator)	0.214	25
7	Paint bake oven incinerator bypass	0.360	195

Results

Data Analysis

The emission rates for each incinerator THC sampling location were calculated using average concentrations for the tests and the measured volumetric flowrate. These emission rates along with the emission rate for the incinerator bypass are recorded in Table 1. (This bypass is vented directly to the atmosphere from the oven off-gas duct and therefore affects the overall control effectiveness.) The average THC concentration at the incinerator inlet was used to calculate the emission rate to the incinerator and the resulting control effectiveness. Using overall test averages for THC concentrations allowed for fluctuations in concentration at the incinerator inlet and outlet. The incinerator emission control effectiveness in reducing THC concentrations was computed to be 86 percent. Likewise, the overall system effectiveness (including the bypass) was determined to be 70 percent.

An energy balance to determine heat exchanger effectiveness was developed as outlined in Figure 2. Heat fluxes were calculated to be as follows:

$$\dot{Q}_{air} = 82 \times 106 \text{ joules/hr}$$
$$\dot{Q}_{exhaust} = 5{,}864 \times 106 \text{ joules/hr}$$
$$\dot{Q}_{gas} = 2{,}731 \times 106 \text{ joules/hr}$$

To implement THC concentration emission control requires additional energy ($\dot{Q}_{fuel}$, $\dot{Q}_{air}$, $\dot{W}_{work}$). The heat exchanger recovers a portion of this energy from the E-coal oven. The effectiveness of this heat recovery system (η_c) is measured as the percent recovery of the additional energy required by the control device, expressed as:

$$\eta_c = \frac{\dot{Q}_{exchanger}}{\dot{Q}_{air} + \dot{Q}_{fuel} + \dot{W}_{work}}$$

$\dot{Q}_{gas}$ is not included since the temperature of the gas from the other paint bake ovens to the incinerator is below that of the E-coat oven and would exist for both controlled and uncontrolled systems. The recovery efficiency computed above is 41.5 percent; if $\dot{Q}_{gas}$ were included to give the overall recovery efficiency, that value would be 32.7 percent.

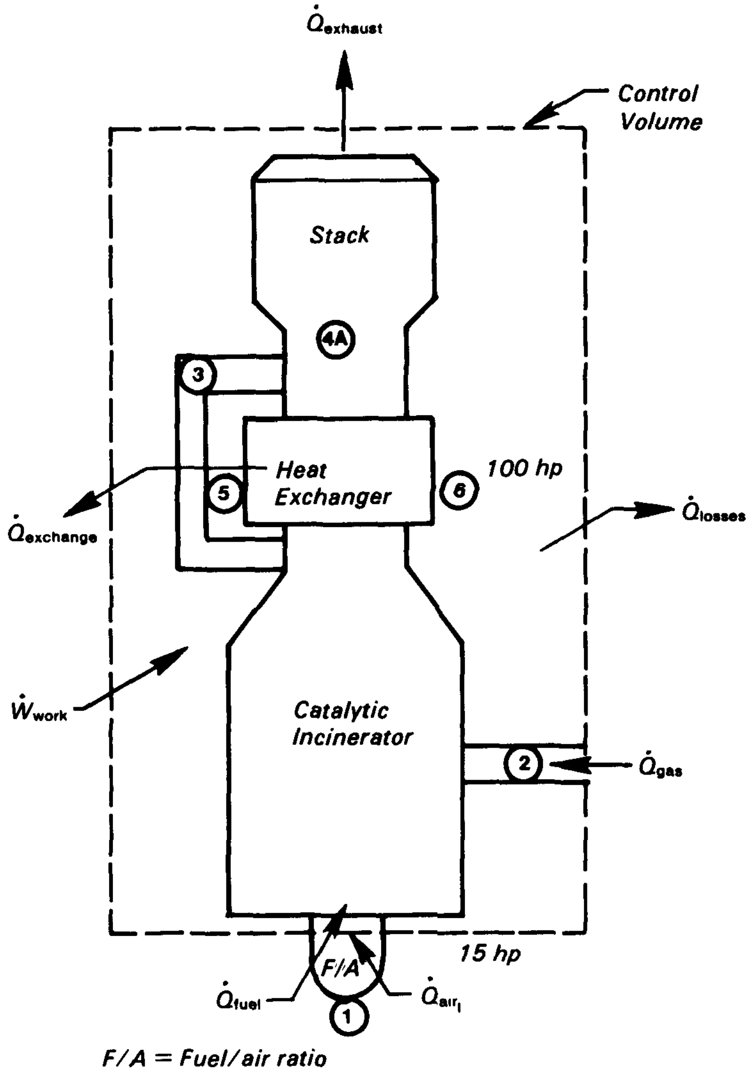


Figure. 2 *Control volume for heat balance.*

Process Analysis

As cited earlier, the THC concentration emission control effectiveness for the catalytic incinerator tested was 86 percent, which was assumed to be the maximum possible for this system operating with less than 20 percent of the catalyst life remaining.

An advantage of this system is its insensitivity to fluctuations in one absorbing and one regenerating bed.

While carbon adsorption can result in near total THC concentration control, the adverse effect of variations in types and concentrations of contaminants requires that its application in facilities similar to the Mack Truck, Inc., paint bake ovens be qualified by similar applications presently in operation.

Cost Analysis

The installed capital costs of thermal and catalytic incineration systems consisting of catalyst beds, preheat burners, ductwork, fan, and controls are $111,100 and $132,000, respectively. The addition of a heat exchanger increases the capital cost approximately 25 percent. The operating cost differential between each pollution control device is impacted further by utility costs, capital recovery costs, and other indirect operating costs (taxes, insurance, administration).

Estimates of the annualized costs in 1977 dollars for thermal and catalytic incineration were $348,000 and $105,000, respectively, and fuel costs were 95 and 78 percent, respectively, of these totals. Thus, reduction in fuel consumption yields high economic returns. Instead of transferring heat to the E-coat oven stream from the incinerator outlet stream, this energy could be used to preheat the incinerator inlet stream. For this configuration and assuming an 82 percent exchanger efficiency as before, the heat recovery would be 38.6 percent as compared to 35.1 percent for the current application. The increased heat transferred per unit heat exchanger area results from the increased temperature differential. This configuration also would eliminate the need for a bypass stream.

The capital cost of a carbon adsorption device is based on the total weight of carbon required for efficient control of the organic material being controlled and the configuration of the system. Based on these assumptions, the annualized costs are $34,000. Since the concentration of pollutants being removed is small, operating costs are negligible compared to the cost of inlet THC concentrations and changes in contaminants. This is assuming the species entering the incinerator do not blind the catalyst or generate particulate matter requiring further control. A disadvantage of the system is the large energy requirement to raise the gas temperature sufficiently for effective catalyst performance. In general, however, increases in the combustible content of the entering gas stream reduce the energy requirement offset.

Thermal (noncatalytic) incineration requires temperatures in excess of 1500°F and residence times from 0.5 to 1.5 seconds; thus, higher energy input to reach operating temperature and construction with heat-resistant materials are required. This energy requirement can be reduced by preheating the gas stream entering the incinerator using heat exchangers or hot gas recirculation. A heat recovery of 35 percent is typical and similar to the 35.1 percent calculated for this catalytic system.

Thermal or catalytic incineration can be used to control THC concentration in a gas stream. Selection of this technology over carbon adsorption is influenced by the economic burden of the additional energy requirement and the potential use of the solvent being controlled. Replacement parts (such as the catalyst) are not included in such determinations. Incineration also precludes recovery of organic species in the gas stream.

Carbon adsorption, on the other hand, uses a bed of activated carbon to absorb organic species, which means its efficiency is impacted by the organic constituents; methane, for example, cannot be effectively controlled by carbon adsorption. The energy requirements (exclusive of gas-moving equipment and instrumentation), however, is low compared to incineration, consisting of stream generation for regenerating the beds and production of cooling water. If organics are not to be recovered, a water effluent would be generated which may require treatment and/or disposal. Carbon, like the catalyst, can be regenerated, having a useful life of five years. Typically, a system consists of removing higher pollutant concentrations. Therefore, although carbon adsorption may appear to be more attractive than incineration for the Mack Truck, Inc., application, it may be economically unattractive in applications with higher concentrations. Also, since Mack Truck, Inc., operates two shifts a day, which allows them to use one catalyst bed and regenerate during the third shift, annualized costs using adsorption may also be reduced further by eliminating the dual adsorption bed design.

Conclusions and Recommendations

The catalytic incineration system tested at Mack Truck, Inc., was effective in reducing organic emissions from the small parts bake ovens. Based on the average emission rates calculated for the three 1-hour tests, the incinerator was capable of reducing organic emissions by 87.2 percent. Bypassing the incinerator with a fraction of the total gas stream resulted in an emissions reduction to the atmosphere of only 70 percent.

The effectiveness of the heat exchanger, used to heat air for the E-coat oven, was 82 percent, allowing for a recovery of 35.1 percent of the total thermal energy from the gas stream entering the heat exchanger. Larger fuel savings may be possible for Mack Truck, Inc., if the combustion air and gas stream being incinerated are preheated (rather than the E-coat oven air) since more energy can be transferred to these streams, thus allowing reduced fuel requirements. A further analysis of the heat exchanger showed that 38.6 percent of the energy required to operate the incineration system could be recovered.

The primary disadvantage of thermal or catalytic incineration is the cost associated with the fuel requirements. Carbon adsorption has lower operating costs than the incinerators but highe capital costs. Since all of these prc cesses can reach near total control (the THC emissions, the major diffei ence between incineration and adsorp tion is the annualized cost of each.

Bruce C. DaRos, Richard Merrill, and William C. Kuby are with Acurex Corporation, Mountain View, CA 94042.
***M. Lynn Apel** is the EPA Project Officer (see below).*
The complete report, entitled "Organic Emissions Evaluation of a Paint Bake Oven with Catalytic Incineration," (Order No. PB 82-116 872; Cost: $9.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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